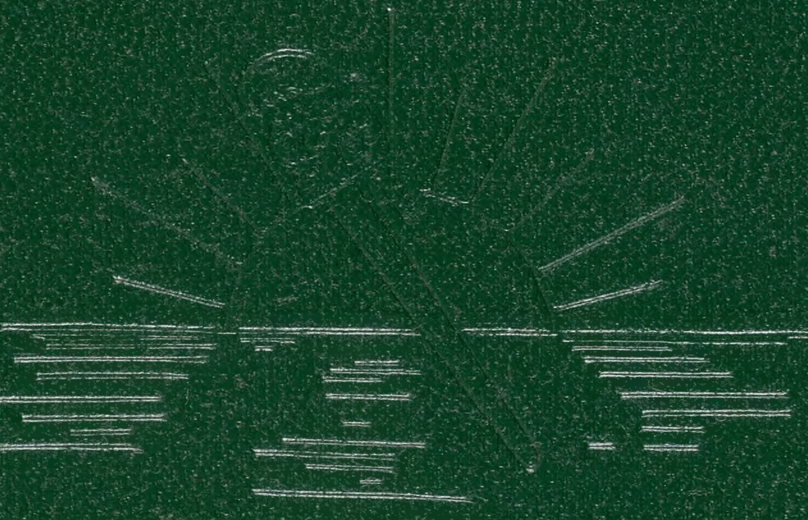
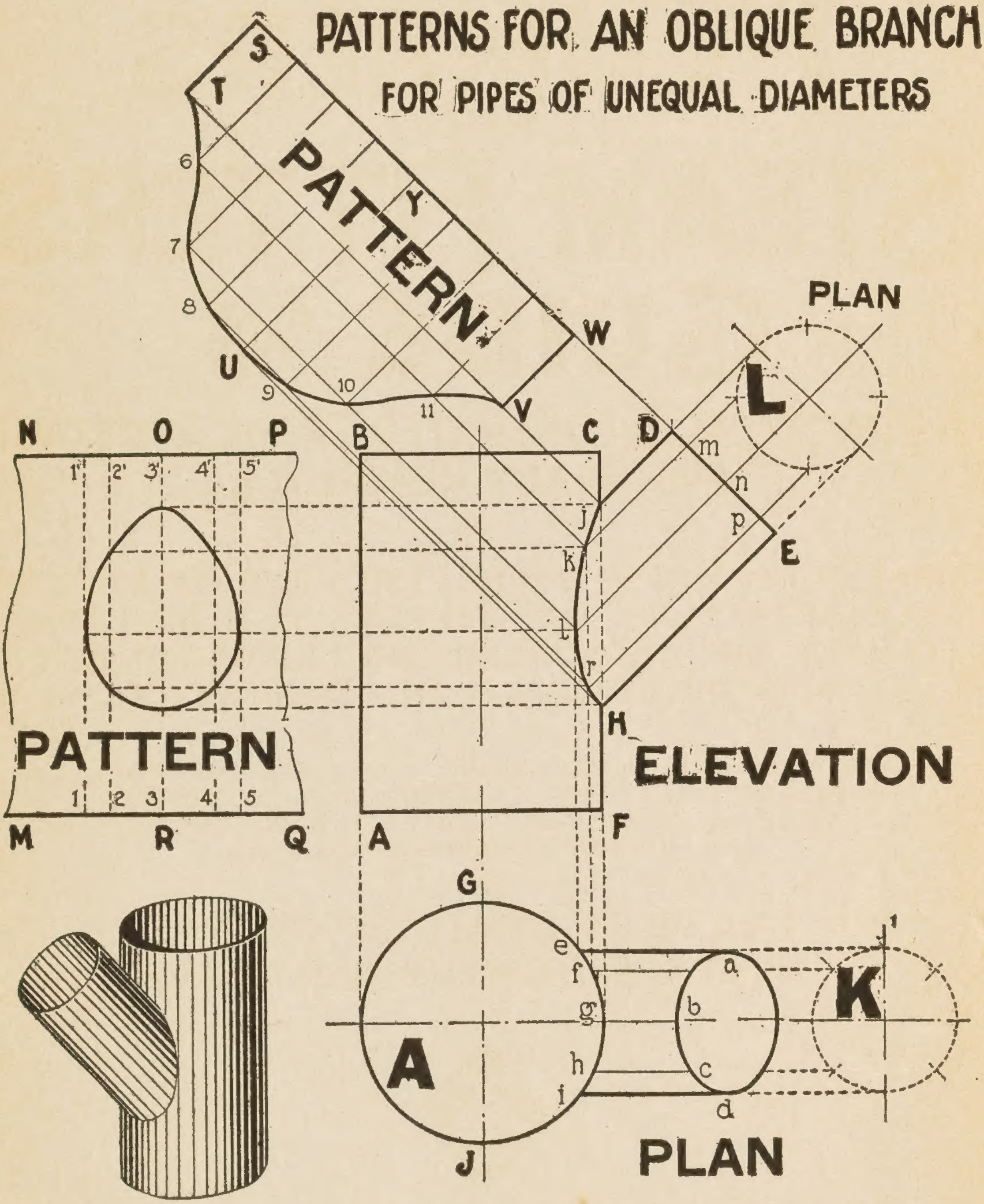
AUDELS PLUMBERS AND STEAM FITTERS GUIDE #4



Sheet Metal Work

PATTERNS FOR AN OBLIQUE BRANCH FOR PIPES OF UNEQUAL DIAMETERS



Problem.—Y branch with run and branch pipes of unequal diameters and development of its patterns. For ***Sheet Metal Work,*** see pages **2,865** to **2,938**; for ***Boiler Plate Work,*** see pages **2,939** to **2,970**.

"BY HAMMER AND HAND ALL THINGS DO STAND"

AUDELS PLUMBERS AND STEAM FITTERS GUIDE #4

A PRACTICAL ILLUSTRATED TRADE ASSISTANT AND READY REFERENCE

FOR

MASTER PLUMBERS, JOURNEYMEN AND APPRENTICES
STEAM FITTERS, GAS FITTERS AND HELPERS,
SHEET METAL WORKERS AND DRAUGHTSMEN
MASTER BUILDERS AND ENGINEERS

EXPLAINING IN PRACTICAL CONCISE LANGUAGE AND BY WELL DONE ILLUSTRATIONS, DIAGRAMS, CHARTS GRAPHS AND PICTURES THE PRINCIPLES OF MODERN PLUMBING PRACTICE

BY

FRANK D. GRAHAM - *CHIEF*
THOMAS J. EMERY - *ASSOCIATE*

THEO. AUDEL & CO. - PUBLISHERS
65 W. 23RD ST., NEW YORK, U. S. A.

Printed in the United States

Foreword

These Guides give first hand reliable practical information in clear and concise form. They illustrate ***Plumbing*** in its many practical applications in the clearest and plainest manner and in a way not to discourage the searcher for practical plumbing knowledge, but to make an interesting, instructive and useful reference for all interested in any branch of plumbing.

In the prepartion of these Guides, the aim of the author has been to present the subject in ***the simplest possible manner,*** because no matter how well informed the reader may be, he absorbs the desired information much more readily when presented in simple, brief language, than he would when confronted with an unnecessary display of technicalities.

The aim throughout has been to simplify and give information on ***every phase of plumbing.***

Frank D. Graham.

OUTLINE OF CHAPTERS

Any general subject can be located quickly and easily by means of the following Outline of Chapters, each of which is practically complete in itself.

READY REFERENCE INDEX

and

READERS' GUIDE

An hour with a book would have brought to your mind,
The secret that took the whole year to find;
The facts that you learned at enormous expense,
Were all on a library shelf to commence.

To the Reader and Student:

Read over this index occasionally and get the habit of looking for *unexpected information.* The ready reference index tells you on what pages to find the information sought for.

When you are interested and want information quickly on a problem in ***Plumbing,*** if you have the habit of consulting these ***Plumbers' Guides*** they will answer your problem.

Learn to use the index; all subjects covered are listed under their proper headings; it is also suggested to look up closely allied subjects for side lights on your problems.

A

B

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CHAPTER 132

Manufacture of Gas

Methods of Making Gas.—There are various ways in which gas is made and these may be designated according to the substance or substances from which the gas is obtained as from

1. Coal.
   a. Bituminous.
   b. Anthracite.
2. Water.
   a. Ordinary.
   b. Enriched.
3. Gasoline.
4. Calcium carbide.

Bituminous Coal Gas.—This is made by heating bituminous coal about four hours in externally heated air tight fire clay retorts. Gas is driven off and a residue called "gas house coke" is left in each retort; this is withdrawn and a charge of fresh coal added.

From the retorts the gas passes into the hydraulic main from which it is withdrawn by the exhauster and pushed to the condenser. In the condenser the gas is cooled by water surrounding tubes through which the gas passes. This condenses the tar and oil carried in the gas to a liquid which flows out at the bottom through water sealed pipes, not shown, into the tar storage tank. From the condenser the gas goes to the scrubber which

MANUFACTURE OF COAL GAS

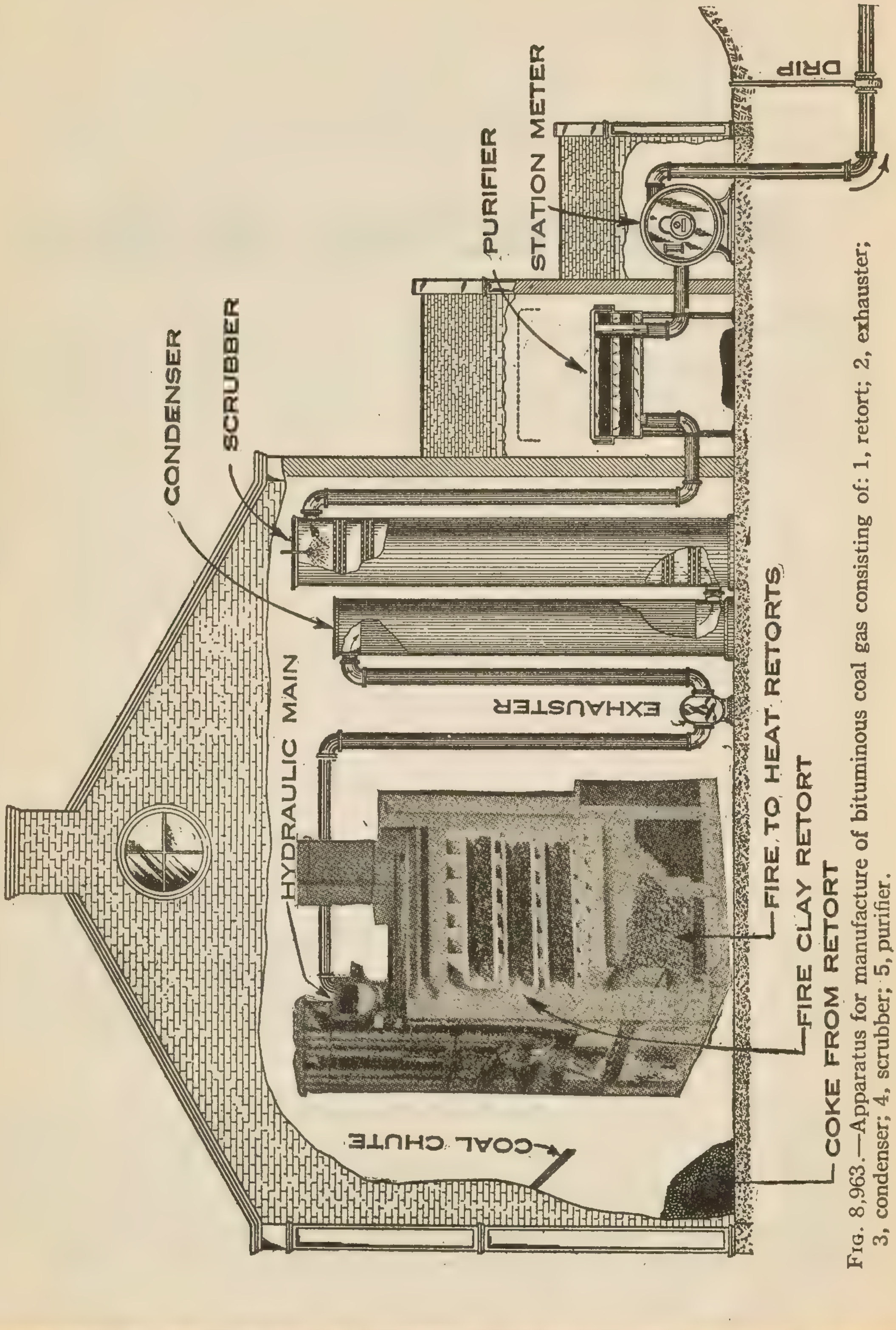


Fig. 8,963.—Apparatus for manufacture of bituminous coal gas consisting of: 1, retort; 2, exhauster; 3, condenser; 4, scrubber; 5, purifier.

consists of a cylindrical tower containing a number of wooden trays having slats running crosswise in checker-board fashion and where a water spray at the top of the tower keeps the slats wet and washes the impurities down over the wet surfaces where the gas gives up its ammonia to the water. This ammonia solution is removed at the bottom through a water sealed drain and delivered to an ammonia storage tank, not shown.

The gas next goes to the purifier, which is a large iron box containing two trays of oxide of iron, where the sulphur impurities in the gas are absorbed by the iron and removed from the gas. The top or lid of the purifier can be raised, as shown by the dotted line above, for changing the oxide. A pile of oxide, undergoing airing, is shown on the floor underneath the purifier. The gas now goes through the station meter which measures the volume and then to the storage holder.

Anthracite Coal Gas.—The method of making gas from anthracite or hard coal is descrbed in the chapter on Gas Producers.

Water Gas.—If water in the form of steam be brought into intimate contact with red hot carbon, hydrogen and carbon monoxide will be made. This is the basic feature of the water gas process. The steam will soon chill the carbon and the carbon must be heated again by shutting off the steam and blowing with air, making the process intermittent.

The fire brick lined generator has a thick bed of coke or coal which is burned by forcing air up through it. Not enough air can be gotten through the thick bed of fuel to completely burn the fuel and the gas given off at the top will be inflammable. The carburetter and super-heater are brick lined shells containing brick laid crosswise, checker-board fashion, so as to leave open spaces between the bricks.

By admitting air at the top of the carburetter and at the bottom of the super-heater, the gas coming from the generator can be burned. The burning of this gas heats the brick checker work and the burned gases finally pass out at the open valve at the top of the super-heater through the stack into the atmosphere.

When the fuel bed in the generator becomes hot enough, the air valves and stack valve at the top of the super-heater are closed and steam, through a connection not shown, is turned into the generator and, passing up

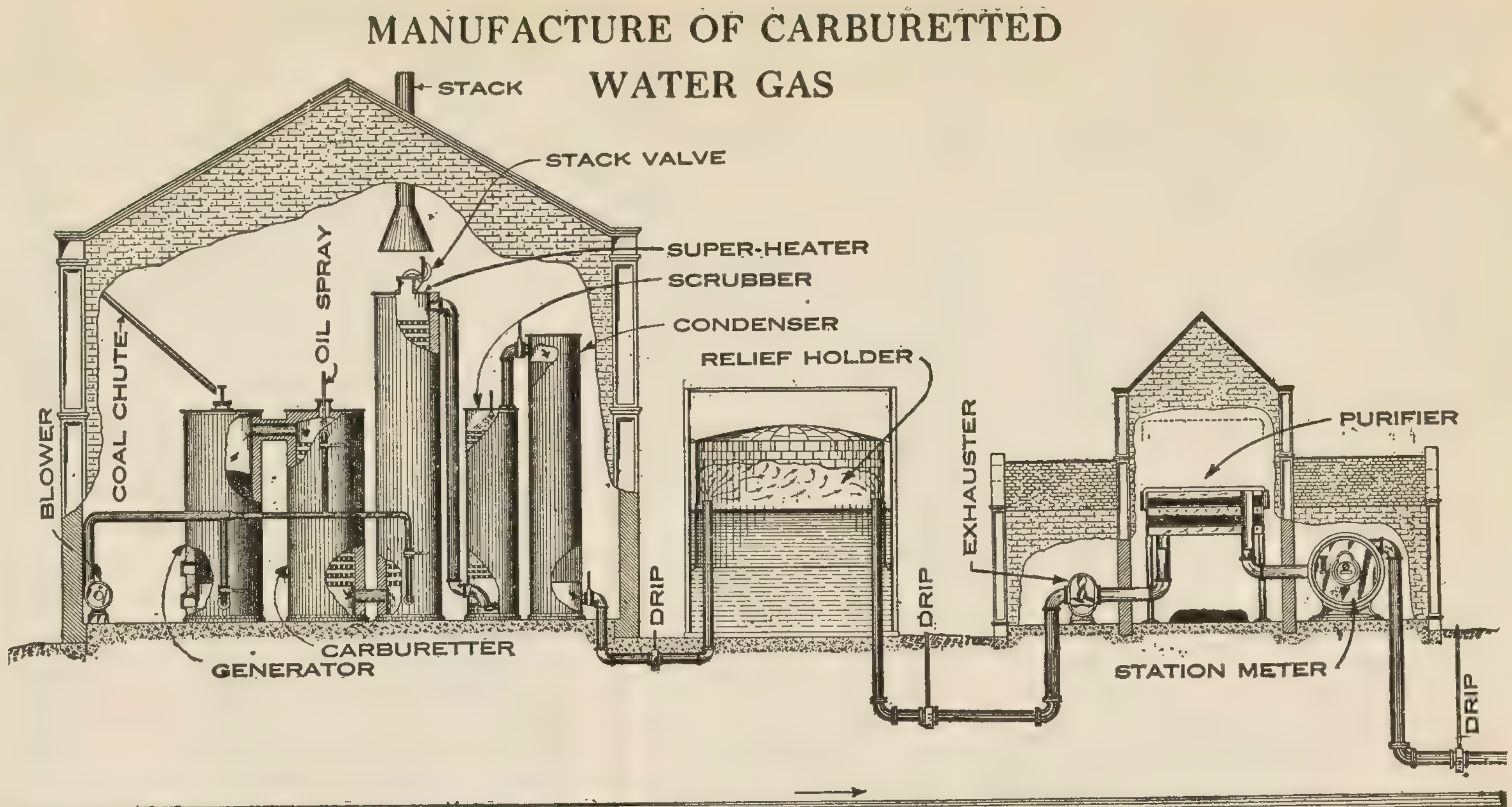


FIG. 8,964.—Apparatus for manufacture of carburetted water gas consisting of: 1, generator; 2, carburetter; 3, super-heater; 4, scrubber; 5, condenser; 6, relief holder; 7, exhauster; 8, purifier.

through the highly heated fuel, forms carbon monoxide and hydrogen. These gases burn with a pale blue non-luminous flame and are known as "blue water gas."

Carburetted Water Gas.—The term carburetted here signifies *oil enriched*. In order to increase the heating value of the blue gas and sometimes give it luminous qualities

(although this is obsolete) oil under pressure is sprayed down over the hot brick work in the carburetter as shown in fig. 8,964. The hot checker brick work in the carburetter and super-heater converts the oil into a fixed gas, this is known as carburetting and the gas is called "carburetted water gas."

The gas entering the bottom of the scrubber must bubble through a water seal and this prevents a return flow of the gas. In many plants this bubbling and sealing is done in a separate box called a "washer."

The scrubber consists of a cylindrical tower containing a number of wooden trays having slats running crosswise in checker-board fashion and where a water spray at the top of the tower keeps the slats wet and the gas is washed clean from its tar and carbon particles.

In the condenser the gas is cooled by water surrounding tubes through which the gas passes. This condenses the tar vapor carried in the gas to a liquid which flows out at the bottom through a water sealed pipe, not shown, into the tar storage tank.

From the condenser the gas goes to the relief holder, which equalizes the delivery beyond on account of the intermittent operation of the process. One complete cycle of getting the fuel bed ready and making a "run of gas," takes about 7 minutes. The relief holder is merely an open top circular tank filled with water in which a smaller open bottom tank is placed so that the gas can fill the space between the water and the top of the smaller inside tank called a "lift."

When the gas volume is increased, the lift rises; when the gas volume is decreased, the lift descends. The weight of the lift produces pressure on the gas.

A shaving scrubber, that is, a steel tower filled with wood shavings, is frequently placed between the relief holder and the purifier in order to catch and remove droplets of tar that may be still remaining in the gas.

The gas is pulled out of the relief holder by the exhauster and goes to the purifier, which is a large iron tank containing two trays of oxide of iron where the sulphur impurities in the gas are absorbed by the oxide and removed from the gas. The top or lid of the purifier can be raised, as shown by the dotted line above, for changing the oxide. A pile of oxide, undergoing airing, is shown on the floor underneath the purifier.

The gas now goes through the station meter, which measures the volume, and then to the storage holder.

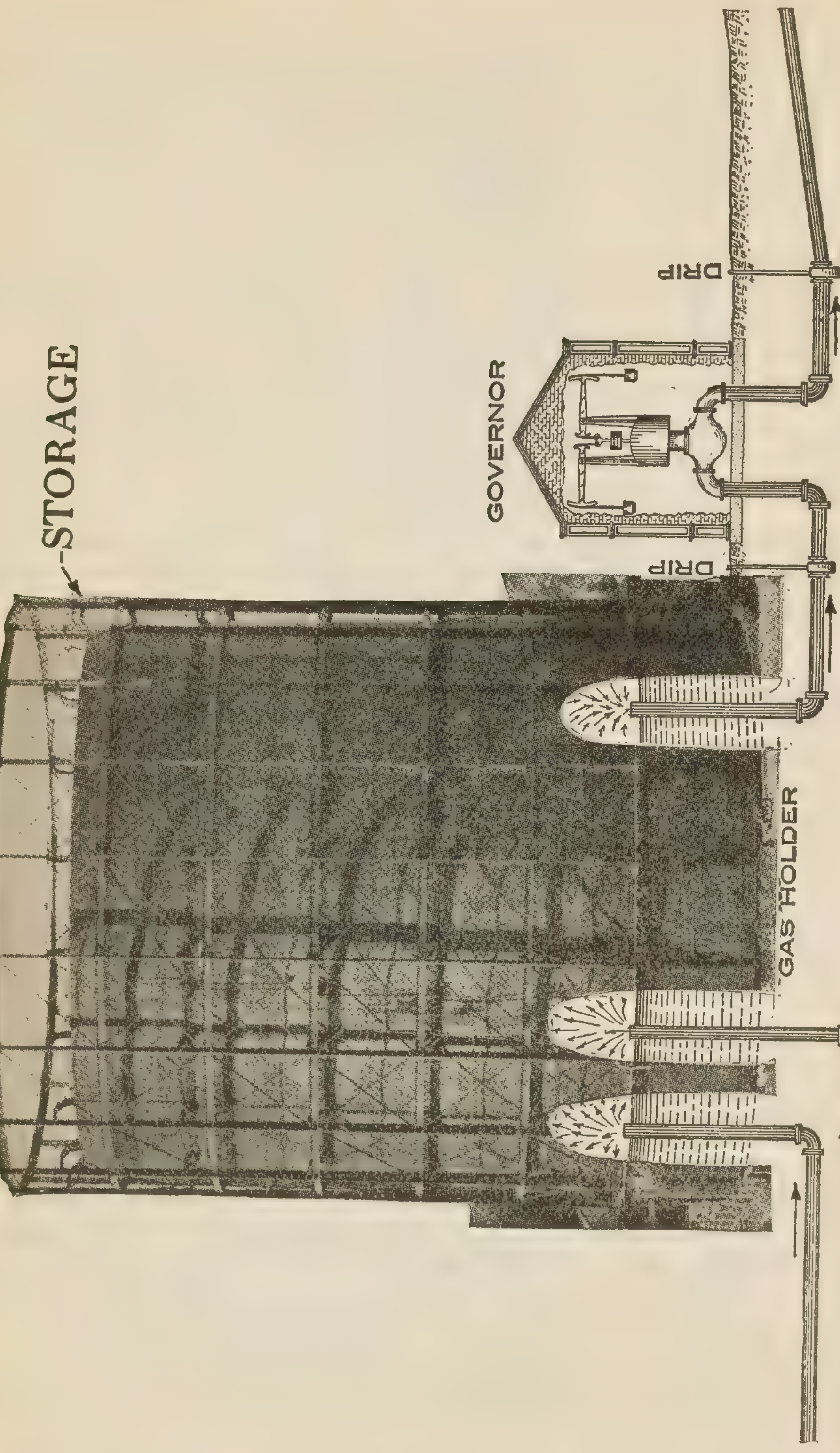


FIG. 8,965.—Storage tank for storing city gas, and governor for regulating the pressure.

Storage.—Gas is made at practically a uniform rate for 24 hours. The rate of use of the gas varies largely during different hours of the day. The function of the holder shown in fig. 8,965 is to equalize the input and output.

The storage holder works on the same principle as the relief holder; however, to increase the capacity, several telescopic "sections" or "lifts" are used over one tank of water and these rise or go down with the increase or decrease in gas volume in the holder. The several lifts have water sealed connections to prevent escape of gas at the telescoping joints.

Governor.—As the gas comes into the holder and raises the telescoping sections, the weight of the metal that the gas must support increases and this increases the pressure on the gas, therefore, the higher the holder is raised the greater must be the resulting gas pressure.

To furnish a nearer uniform pressure to the consumer, the gas now goes through a governor shown in fig. 8,965 which is merely a mechanical device where a variable intake pressure is changed to a practically uniform pressure in the distributing mains.

Delivery of Gas.—From the governor the gas goes into the street mains, through the curb cock, shown in fig. 8,966 service line, house meter and to the consumer's appliances.

Manufactured gas contains condensable constituents that collect in low places in the mains; therefore, drips are necessary and must be pumped out at intervals.

In some plants, Chicago, for instance, when the gas comes out of the storage holder, it is compressed and carried through medium pressure lines to various districts and the pressure then reduced. This is more economical in certain plants than to carry all the gas the entire distance at low pressure.

Use of Gas.—Gas service is radically different from every other kind of public utility service in that the gas cannot be used by the consumer as received, but—first, must be mixed

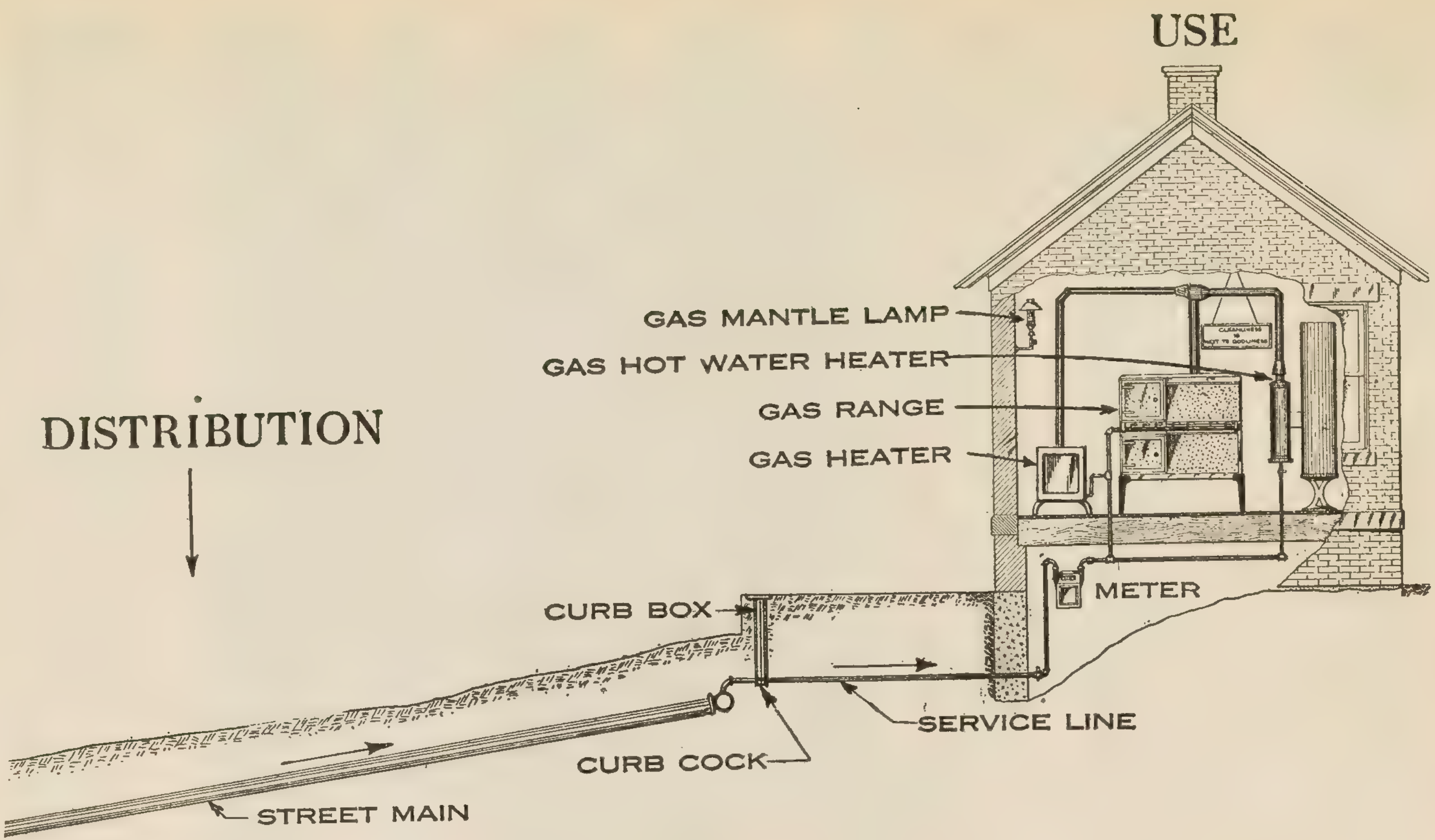


FIG. 8,966.—Distribution of gas through underground mains and various consuming devices.

in proper proportion with atmospheric air by the consumer at the burner; second, this mixture must then be completely burned; third, the flame must be so directed that the heat generated will effectively get into the food, air, water, or mantle that is being heated, with a minimum loss.

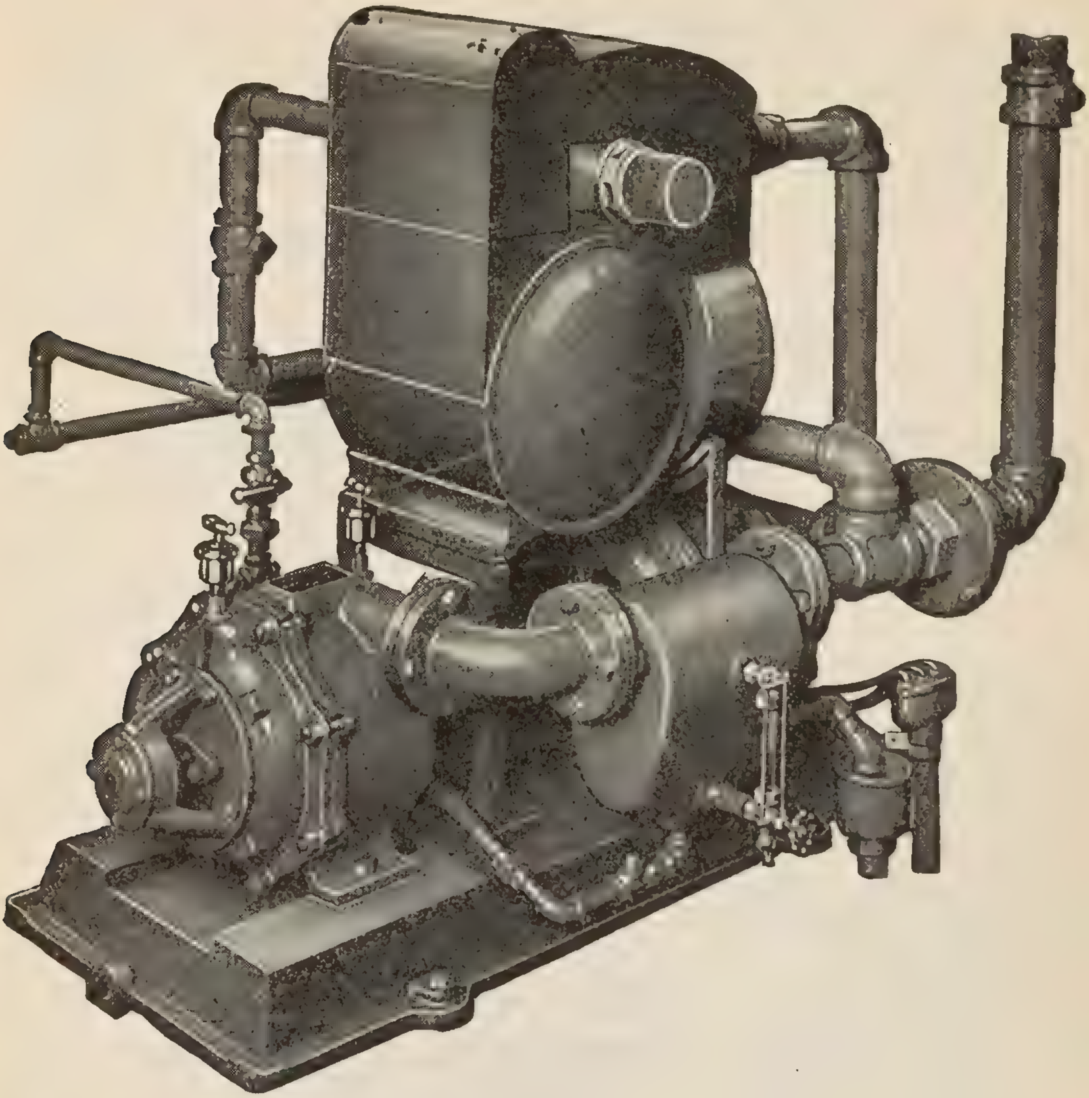


FIG. 8,967.—Reeves pre-mixer. The object of the Reeves system is to deliver city gas to the various factory appliances thoroughly mixed with its required complement of air, to deliver this mixture at constant pressure with a single valve control, and to do this without distributing an explosive mixture through the factory pipes. The Reeves pre-mixer consists of a pre-mixing apparatus and a specially designed blower for ordinary use, or a hydro-turbine compressor for high temperature work. In the Reeves method, one part gas and two-thirds air are pre-mixed. This ratio is predetermined and the mixer adjusted at the factory to deliver this ratio. The mixer is then entirely sealed so that no one can disturb this adjustment. After the gas and air are mixed the mixture is then compressed and delivered at from ½ to 3 lbs. pressure to the inspirator where additional air is entrained by the velocity of the pre-mixed flow. One valve controls the pre-mixed velocity and once the inspirator is adjusted, the resulting mixture remains proportionate regardless of the amount consumed, making low burner adjustment possible without back-firing. The homogeneous mixture attained reaches the burner at pressures unobtainable with any other method, giving the highest possible flame temperature.

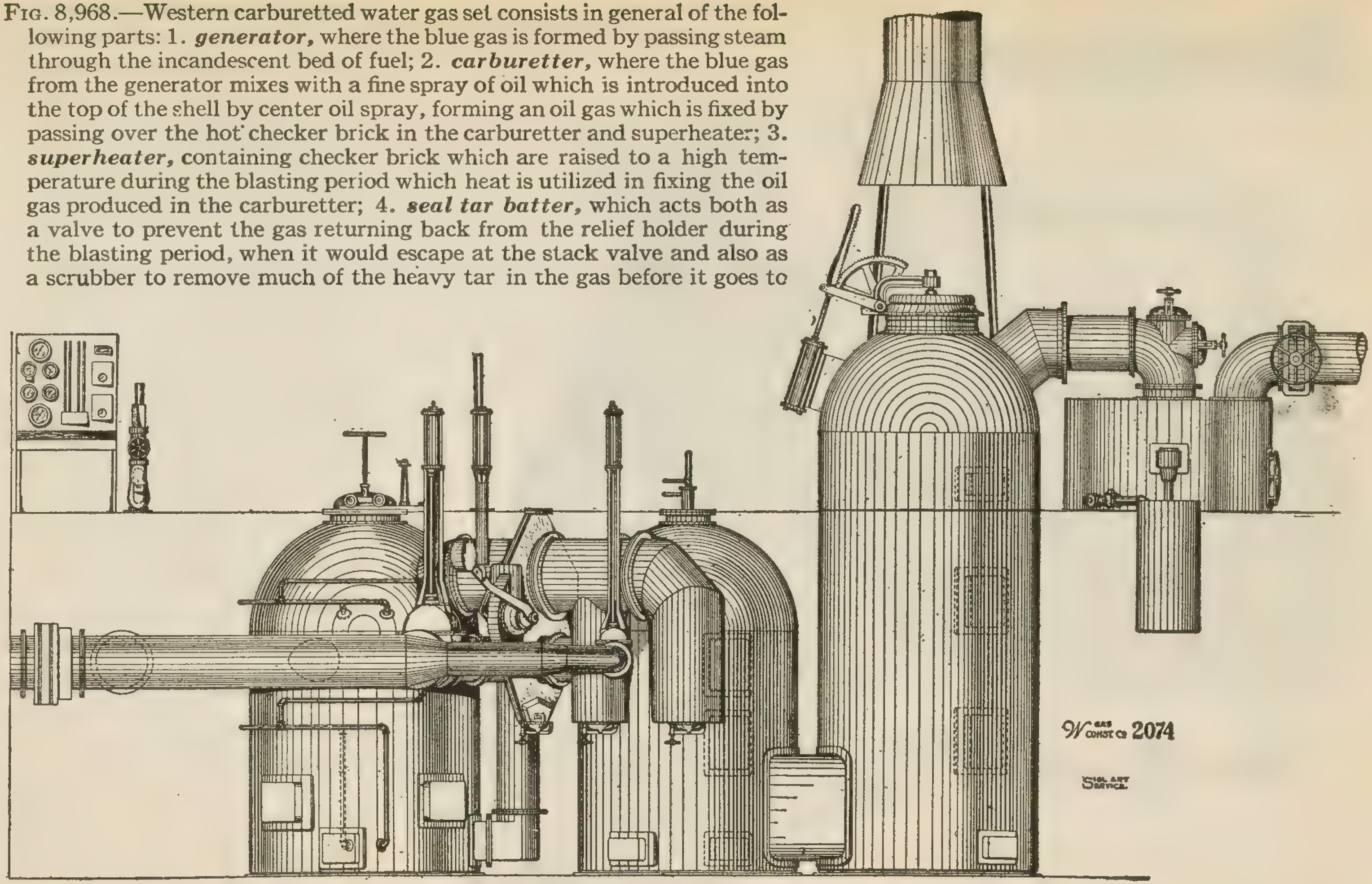


FIG. 8,968.—Western carburetted water gas set consists in general of the following parts: 1. ***generator,*** where the blue gas is formed by passing steam through the incandescent bed of fuel; 2. ***carburetter,*** where the blue gas from the generator mixes with a fine spray of oil which is introduced into the top of the shell by center oil spray, forming an oil gas which is fixed by passing over the hot checker brick in the carburetter and superheater; 3. ***superheater,*** containing checker brick which are raised to a high temperature during the blasting period which heat is utilized in fixing the oil gas produced in the carburetter; 4. ***seal tar batter,*** which acts both as a valve to prevent the gas returning back from the relief holder during the blasting period, when it would escape at the stack valve and also as a scrubber to remove much of the heavy tar in the gas before it goes to the relief holder; 5, ***blower,*** for producing the necessary blast to raise the temperature of the machine; 6, ***reversing valve,*** by means of which the capacity of the machine is increased and an increased economy in fuel consumption obtained owing to the reversal of the direction of the flow of steam in the generator; 7, ***generator blast valve,*** for regulating the supply of air to the generator; 8, ***carburetter blast valve,*** for regulating the supply of air to the carburetter.

The results obtained will depend primarily on the gas utilization appliance and the consumers' skill and care in operating. All these operating features are beyond the gas company's control, but are vital in determining the quality of the service produced by one consumer and the effect on the service of other consumers. A thorough understanding of the appliance situation in the home is, therefore, of vital interest to the gas user. Fig. 8,966 illustrates the use of gas.

Kind of Gas Used.—In some plants coal gas only is used, in others water gas only is used, and in others both are made and mixed.

At the present, about 60% of the gas sold as a public utility service in the United States is carburetted water gas. The percentage of acetylene and oil gas is small.

Due to changing fuel conditions, the obsolete candle power standard should be abandoned and the heating value standard lowered so as to permit a more economical utilization of cheaper raw fuels.

The beehive coke ovens in the United States waste annually about 150 billion cubic feet of gas, which is equal to nearly one-half of all the manufactured gas sold in the United States. This could largely be saved with a lower heating value standard and then making more coke in by-product coke ovens.

The term "artificial" has frequently been used for manufactured gas; however, as the gas is manufactured from crude fuel, the term "manufactured gas" is better. That is, the gas is "man-made" in distinction to the "nature-made" natural gas.

Because of the early use of manufactured gas in open flame burners where luminous properties were essential—

although the mantle lamp now makes this obsolete—the term "illuminating gas" has frequently also been used.

CHAPTER 133

Gas Producers

Gas Producers.—A gas producer is *an apparatus for producing gas, on a small or medium scale, especially for fuel.*

Processes Within the Producer.—The first two reactions in the generator constitute what is termed incomplete combustion, consisting of the formation of ***carbon dioxide*** and the decomposition of the compound into the ***monoxide.*** The result of the process is the same as if the pound of carbon had been burnt directly to carbon monoxide, thus developing 4,451 *B.t.u.* for each pound of C, burnt to CO. This heat is apparent as the sensible heat of the fuel bed and generator.

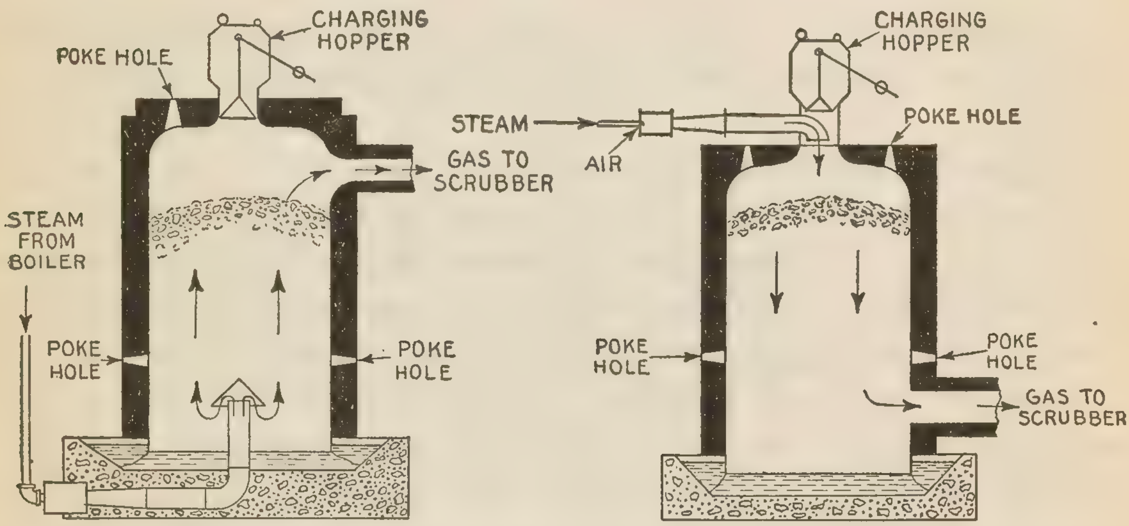
The carbon monoxide may be caused to combine with fresh oxygen at any time after it has left the producer, this second combustion to CO_2 being accompanied by the evolution of $14{,}544 - 4{,}451 = 10{,}093$ *B.t.u.*, the heat value of CO to CO_2 per pound of carbon contained.

Now, atmospheric air is a mechanical mixture of oxygen, which supports combustion, and of nitrogen, which is an inert gas serving as a diluent. The proportions, by weight, are: oxygen, 23 per cent.; nitrogen, 77 per cent. Therefore, accompanying and diluting the 2½ pounds of carbon monoxide resulting from the reaction in the producer, there will be about 4.46 pounds of nitrogen, the whole forming about 6.8 pounds of lean gas.

Use of Steam in Connection with Gas Producers.—The object of the gas producer being the generation of a combustible gas of high heat value, it is desirable to use as little as possible of

the inherent heat energy of the fuel during its gasification. The only sensible heat necessary is that which raises the fuel to incandescence so as to reduce the carbon dioxide to monoxide.

Now, there are some 4,451 heat units generated in burning a pound of carbon to carbon monoxide, and as only part of this heat passes away with the gases or is dissipated by radiation from the generator, it may be said that there is a surplus of about 2,500 *B.t.u.* per pound of carbon over and above what is necessary for the working of the furnace. This extra heat requires to be utilized in order to get the greatest efficiency from the gener-



FIGS. 8,969 and 8,970.—Gas producer types; fig. 8,969, pressure up draught; fig. 8,970, pressure down draught.

ator and to keep the temperature down, a temperature of 1,900° Fahr, having been found to give a minimum of CO_2 or a maximum of CO.

This surplus of heat is utilized in an effective manner by the introduction of steam into the generator.

Each pound of steam on being decomposed, liberates $^1/_9$ pound hydrogen and $^8/_9$ pound oxygen, the latter combining with ⅔ pound carbon to form $1^5/_9$ pounds of carbon monoxide, this extra amount being produced without the introduction of any more inert nitrogen into the apparatus.

In order to effect the decomposition of one pound of steam, in the presence of incandescent carbon, 6,800 heat units are necessary, and as there are only about 2,500 *B.t.u.* available for the purpose from the burning of each pound

of carbon, the quantity of steam that can be taken care of is $\frac{2,500}{6,800}$ or about .37 pounds. This yields about .325 pound of oxygen which combines with about .245 pound of carbon, yielding .57 pound of the monoxide, which is equivalent to saying that about one-fifth of the total carbon can be gasified by the aid of the steam. The hydrogen liberated will be about .033 pound for each pound of total carbon gasified in all reactions.

Classes of Gas Producer.—With respect to the control of the air passing through the machine, producers may be classified as:

1. Pressure producers;
   - *a.* Up draught;
   - *b.* Down draught.
2. Suction producers;
   - *a.* Up draught;
   - *b.* Down draught.
3. Combined up and down draught.

and with respect to the kind of coal used, as

1. Anthracite.
2. Bituminous.

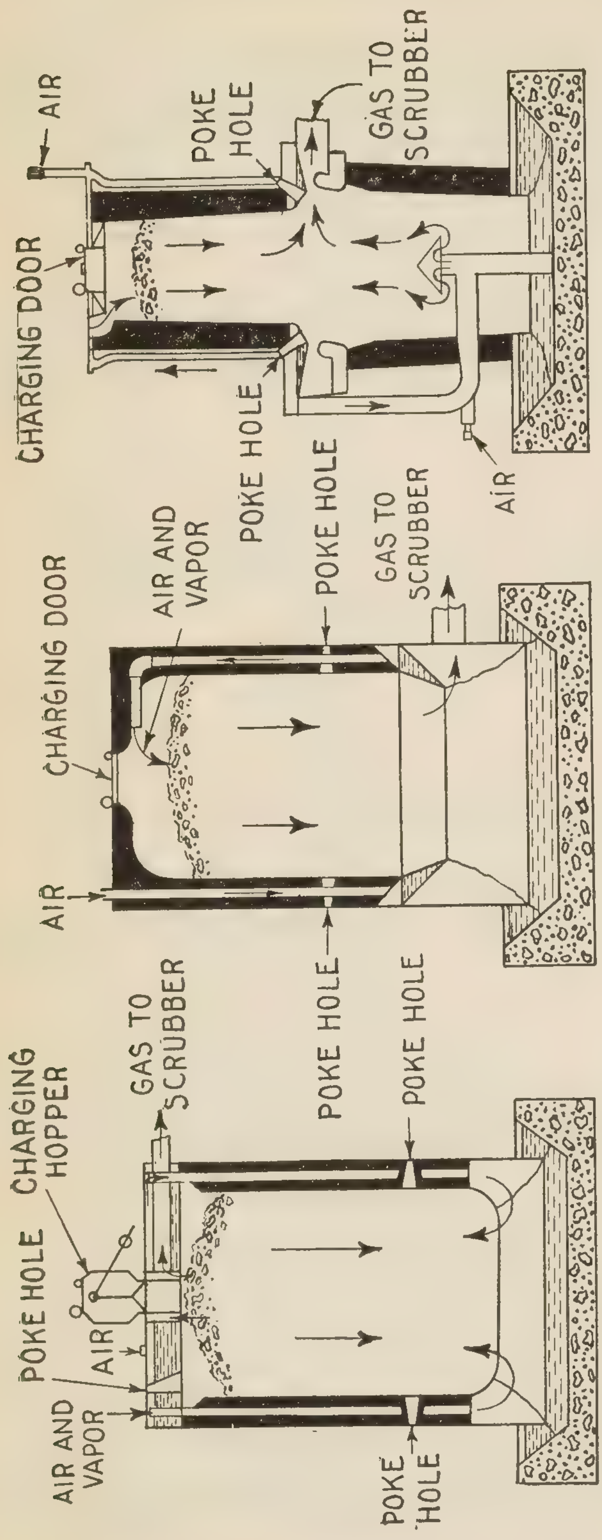
In the pressure system, the air required for the generation of the gas is delivered to the gas producer under pressure derived from an auxiliary source, and the gas generated in the producer is delivered to the engine under the same pressure.

The ***up draught*** pressure producer is used principally with bituminous coal.

The ***down draught*** pressure producer has not been introduced into commercial practice because of the complicated feeding devices.

Morever, whenever fuel is changed or stoking is necessary, it interferes with the gas production and causes irregularity in the operation.

In the ***suction system,*** both the passage of the air through the producer and the introduction of the gas generated therein into the cylinder of the



FIGS. 8,971 to 8,973.—Gas producer types; fig. 8,971, suction up draught; fig. 8,972, suction down draught; fig. 8,973, suction two zone producer.

engine is effected by the sucking action of the piston during its forward or charging stroke.

For anthracite coal and high grade of charcoal and coke, the up draught suction producer is used and may be considered a standard type.

The down draught suction producer is adapted to various bituminous coals, and also low grade fuels as lignite, various woods, refuse, bagasse, coke, charcoal of the lower grades, and peat. Due to the down draught principle, the gas leaving the generator is clear and free from all heavy hydrocarbons, which, after distillation, are broken up into fixed gases by being drawn through the incandescent fuel bed.

Although the pressure producer is usually composed of more cumbrous apparatus, and requires more space for its installation, it possesses greater elasticity than the suction system for meeting variations in fuel conditions, and has greater capacity for utilizing different kinds and cheaper grades of fuel. It is undoubtedly the better for use in connection with large power units, and in cases where several gas engines are operated from the same producer plant.

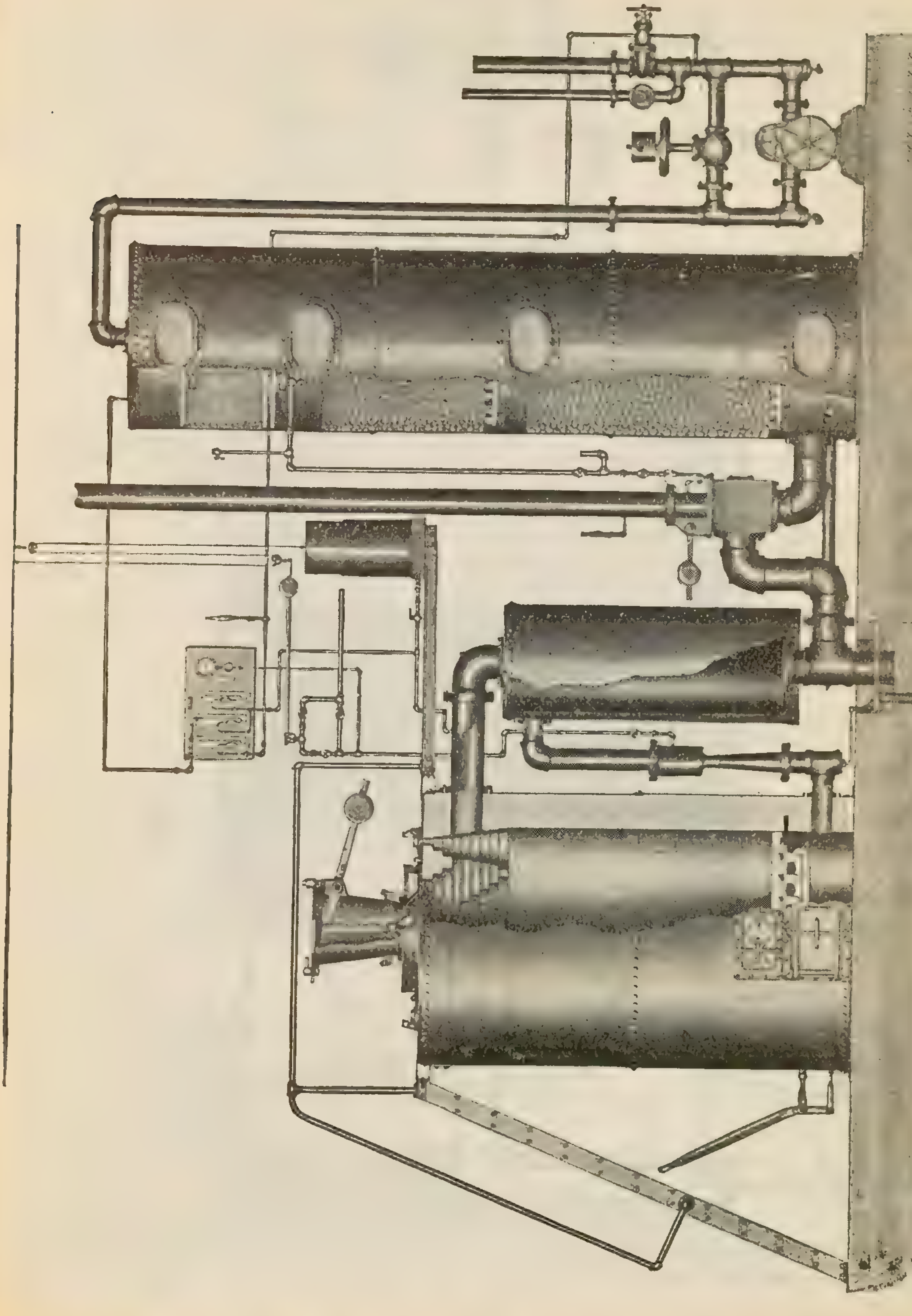


FIG. 8,974.—Flinn & Dreffein *anthracite* gas producer plant for burners and furnaces.

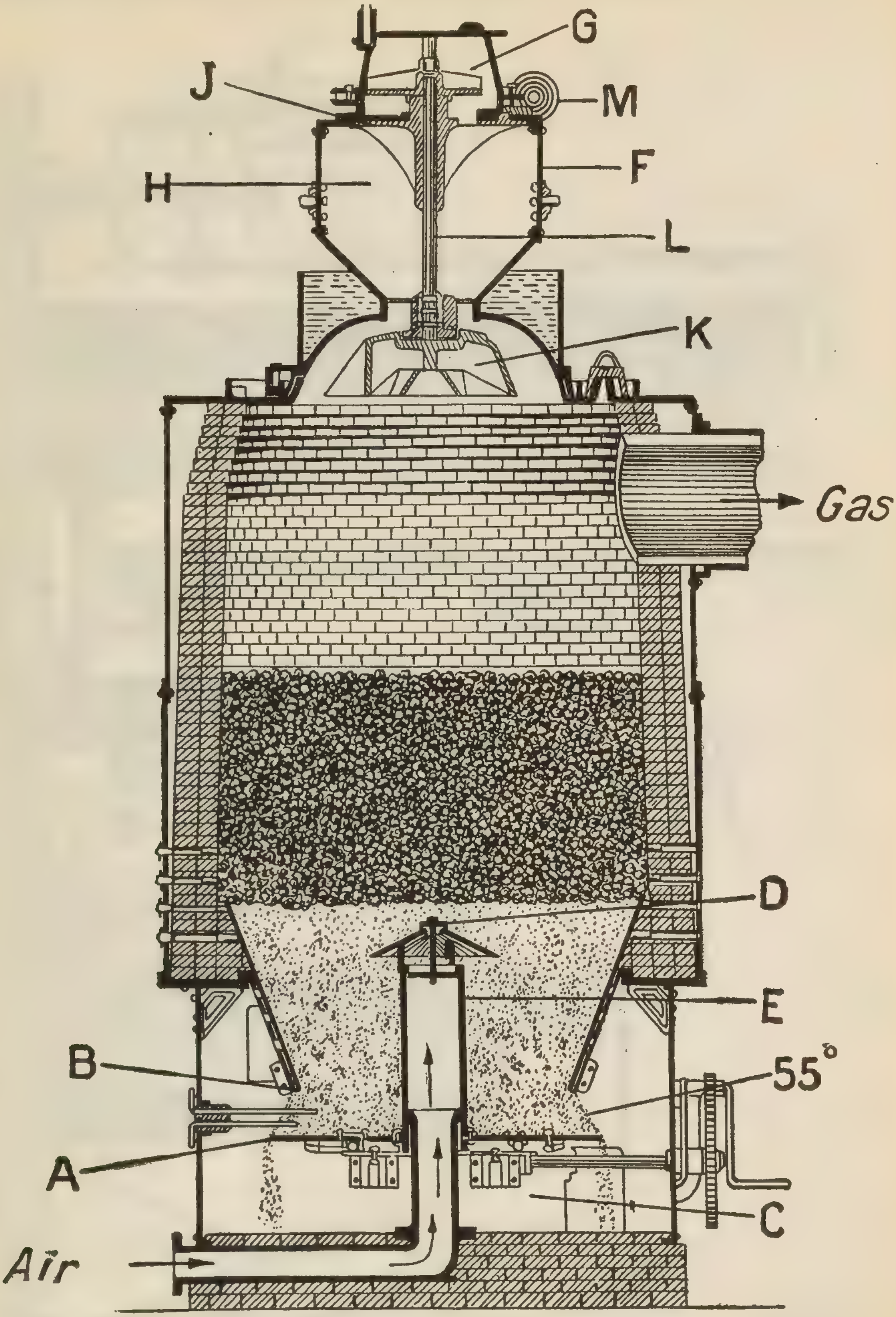


FIG. 8,975.—Cross section of a typical gas producer of the pressure type using anthracite coal, as described in the accompanying text.

On the other hand, for isolated plants of small capacity, or where only a single gas engine of medium power is used intermittently the application of the suction system not only enables the simplification of matters relative to bulk and the reduction of cost, but it affords the more important advantage of making the demand of the engine for gas the controlling factor in the generation of the gas from the solid fuel.

The combined up-and-down draught producer is virtually a down draught suction producer placed on top of an up draught suction producer the gases being taken off at the center. An objection to this type is that more skilled labor is required to secure satisfactory results than the other type, the variations in the load and fuel requiring very close attention.

How a Producer Operates.—Fig. 8,975 shows a section of a typical producer of the pressure type using anthracite coal. The incandescent fuel is supported upon a bed of ash, this resting on a revolving table, A, which is larger in diameter than the bosh, B, the ashes forming a natural slope of about 55°. As they are formed, the ashes fall into the sealed ash pit, C.

In regular operation, the line between the ashes and fuel is kept ahout six inches above the cap D, of the central air pipe E, so that the fire comes into contact with the brick lining only, all iron work being kept away from the heat. This height is maintained constant by grinding or revolving the ash table once every 6 to 24 hours according to the rate of working.

The blast is usually furnished by a steam jet blower, but a fan blower may be used if more convenient, a small steam pipe being run into the vertical air pipe to supply the steam required for softening the clinkers and maintaining the proper temperature of the producer. This producer is equipped with a continuous *automatic feed device* F, which consists of a *receiving hopper* G, surmounting the main *storage magazine* H, the communication between the two being regulated by a horizontal *rotary register* J, operated by a lever. The *distributor plate* K, is suspended below the main magazine and is supported by a steel shaft L, which passes upward through the storage

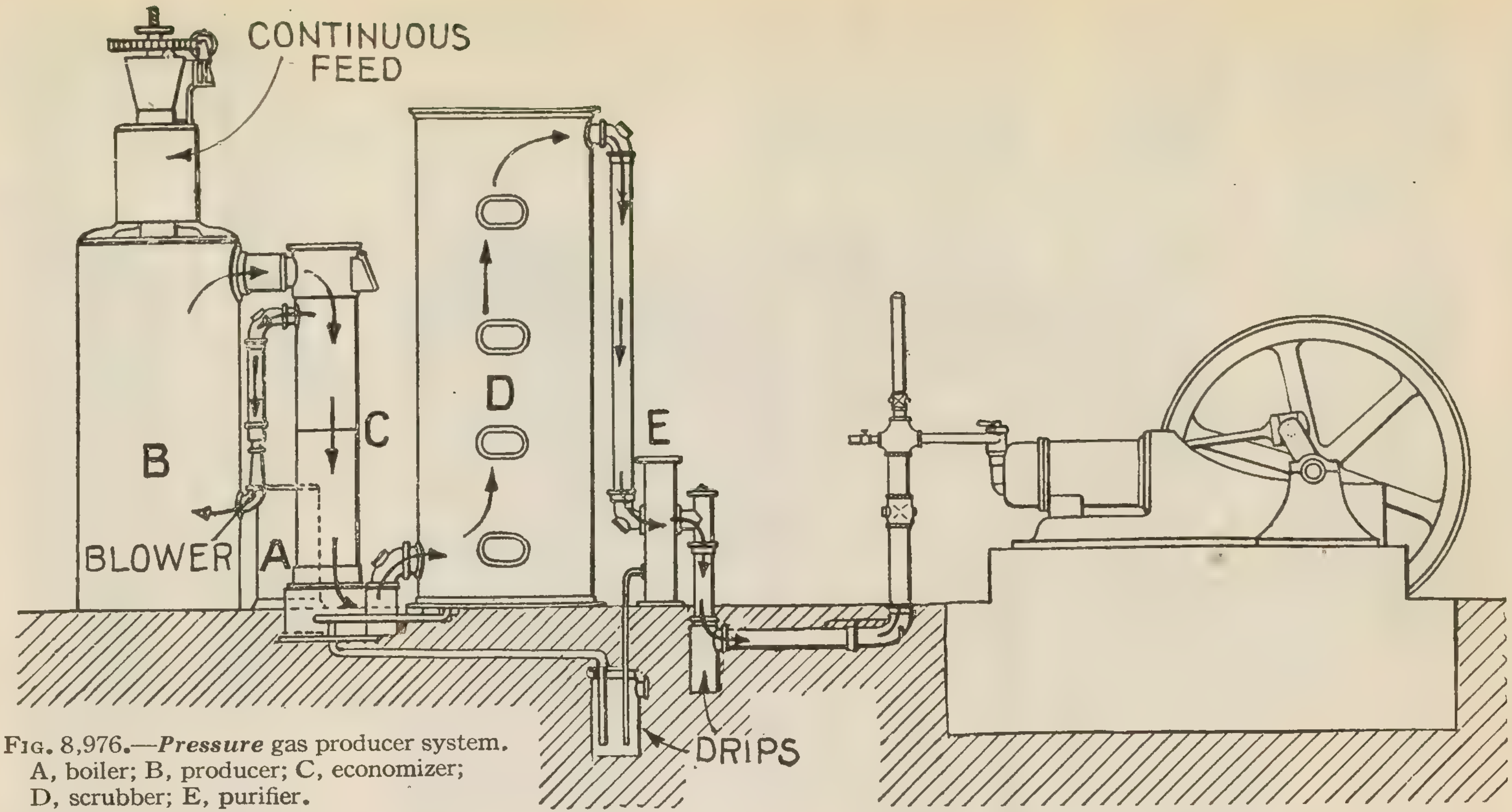


FIG. 8,976.—***Pressure*** gas producer system. A, boiler; B, producer; C, economizer; D, scrubber; E, purifier.

NOTE.—***The pressure producer*** was invented and developed long before the suction producer came into use. ***In this system,*** air is forced into the producer by either a jet of steam or a blower, under a pressure of a few ounces per sq. in. After the gas leaves the producer it is cooled, scrubbed and purified, and then passed into a gas holder of considerable size, from which source it is drawn to the engine for consumption. The gas is permanent and fixed and may be economically transmitted any distance for power and metallurgical purposes. In one class of pressure producer the valuable by-products of soft coal, tar and ammonia are separated during the process of gasification and form a valuable commercial asset. The latter's system of production is called "the recovery process of pressure producers." The ordinarily well designed pressure producer will operate on a thermal efficiency of 80 per cent, but if the exhaust gases from the engine be utilized to the full extent in preheating the air entering the producer, a thermal efficiency of 90 per cent may be obtained.

cylinder. Both the hood of the distributor plate and the inverted conical base of the magazine are water cooled, thus facilitating the discharge of strongly caking coals. The receiving hopper is rotated by means of a worm wheel and worm attached to the upper end of the shaft, and the distributor plate is revolved through the radial arms and hub of the receiving hopper, which are also keyed to the shaft. A *hand wheel nut* on the threaded end of the axis affords the means for adjusting the distance between the distributor plate and the coal reservoir. This adjustment, together with the variable speed secured by means of the step cone pulley M, permits of a ready control of the rate of coal discharge.

Pressure Gas Producer System.—As shown in fig. 8,976 a pressure gas producer system usually consists of the following parts:

A small steam *boiler*, A, for making steam and producing the necessary air pressure; a gas *producer*, B, equipped, with a continuous feed arrangement; an *economizer*, C, with *superheater* and *wash box* a *scrubber*, D, a *purifier* E. The details of the several parts may be considerably modified to suit varying conditions.

For instance, the boiler may be omitted in cases where steam is procurable from any other convenient source, or, in some cases, the separate steam generator may be absolutely unnecessary.

For smaller equipments, or those suitable for operating engines ranging in power up to 500 horse, single producers are considered sufficient.

Larger equipments should be provided with two or more producers, the general design and arrangement of which may be varied to suit the local conditions.

NOTE.—***Demands for gas fuel*** are becoming more and more numerous and producer gas, because of its many advantages, is surely supplanting other gases for industrial use. Coal or coke suitable for use in gas producers is easily obtained and the plants for gasifying these fuels are simpler in operation and less costly for installation and maintenance than the plants for gasifying most of the other fuels which have been used for gas making. Any gas supply to be satisfactory to the present day manufacturer must be efficient and dependable. Variations in the quality of the gas and fluctuations in the supply of gas both cause trouble. Hence it is highly desirable that a gas making machine shall produce gas of uniform quality steadily day after day. Such performance can result only from the following of correct mechanical principles and the use of excellent materials in the construction of the producer.

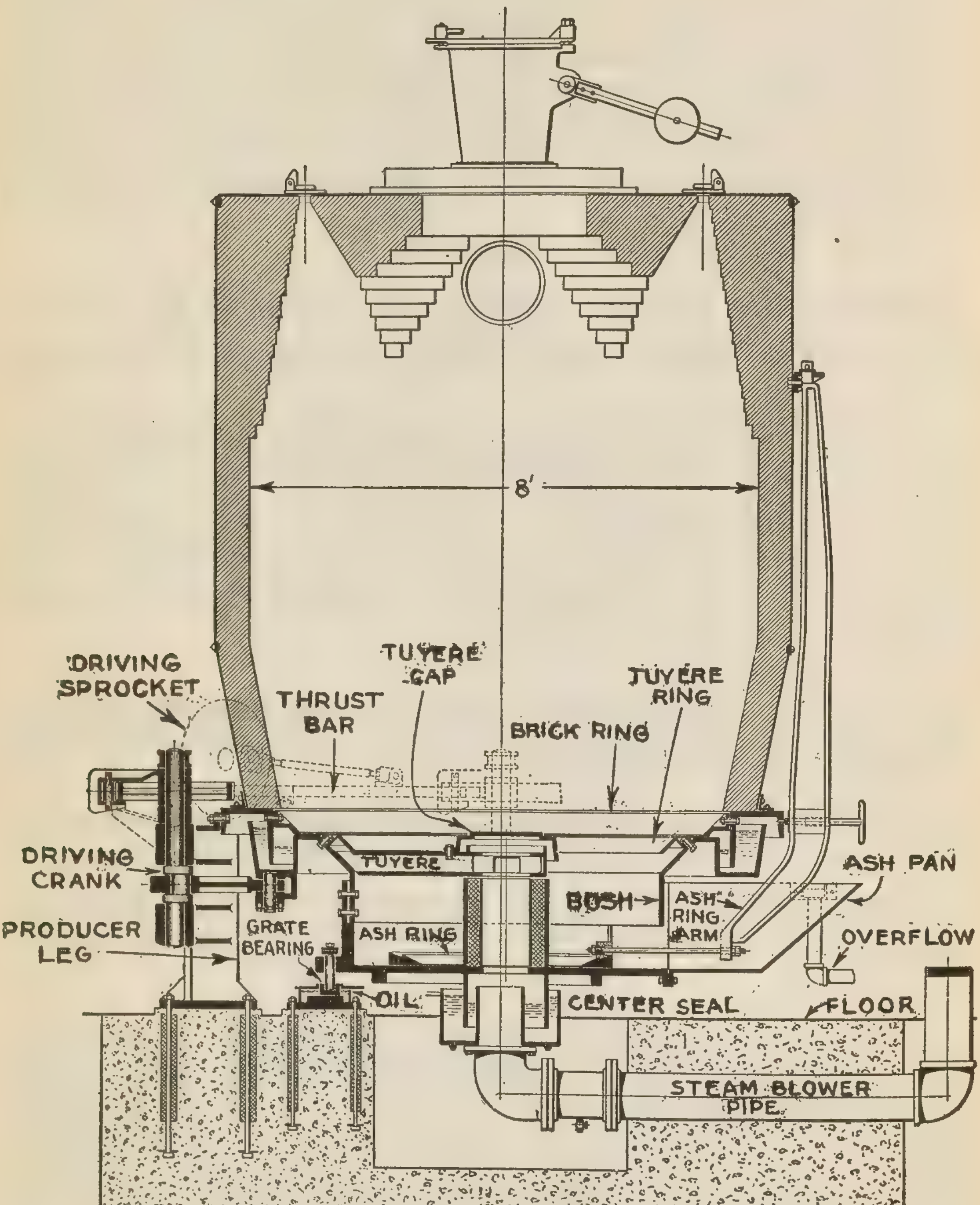


FIG. 8,977.—Flinn & Dreffein *anthracite* mechanical gas producer.

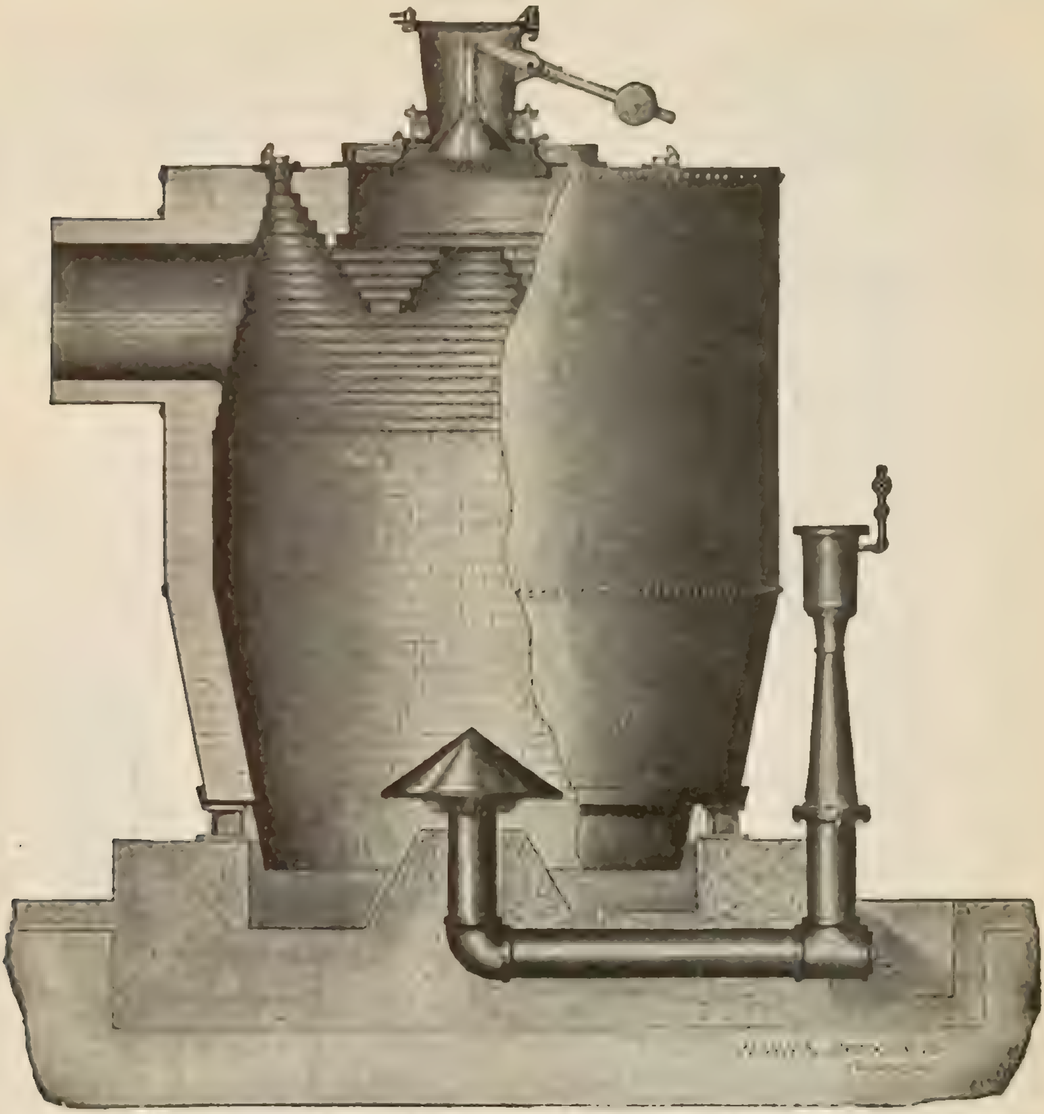


FIG. 8,978.—Flinn & Dreffein ***bituminous*** gas producer. Bituminous coals differ from anthracite coals in that they possess a large percent of volatile hydrocarbons. These hydrocarbons are made up of olefiant gas (C_2H), methane (CH_4) tar, etc., and must pass off into the gaseous state before being burned. These constituents are high in heat value. Obviously, in the generation of producer gas from bituminous coals, heavy hydrocarbons will exist in the form of gas only so long as the producer gas is hot. For this reason, it is desirable to transmit bituminous producer gas hot and burn it before it cools. This is entirely practicable, and the uses of hot bituminous producer gas cover a large field of industrial heating operations. The above producer consists of a heavy steel cylindrical shell, fire brick lined, set in a concrete pan and supported by four legs. A water cooled top prevents excessive radiation from that direction. A large double sealed coal hopper rests on the top. The ash and fuel column rests on the bottom of a concrete pan. A clearance of some 14 ins. all around the bottom of shell and floor of pan permits access from all sides for the removal of ashes. Water is carried in the pan to a level of about 4 ins. above the bottom of shell, which seals the generator, thus preventing leaks. Air and steam for combustion are supplied by a steam blower and the mixture is uniformly distributed over the fuel area by means of a tuyere.

In operation, the gases generated in the producer enter the superheater and economizer. In the economizer the air blast of the producer travels in a direction opposite to that of the blower, and the gas passing through the wash box deposits a large portion of its extraneous suspended matter. Here also is located the seal or non-return against the gases stored in the holder and present in the other parts of the system.

From the wash box the gas enters the scrubber, in which it travels against sprays of water through compartments filled with coke and is still

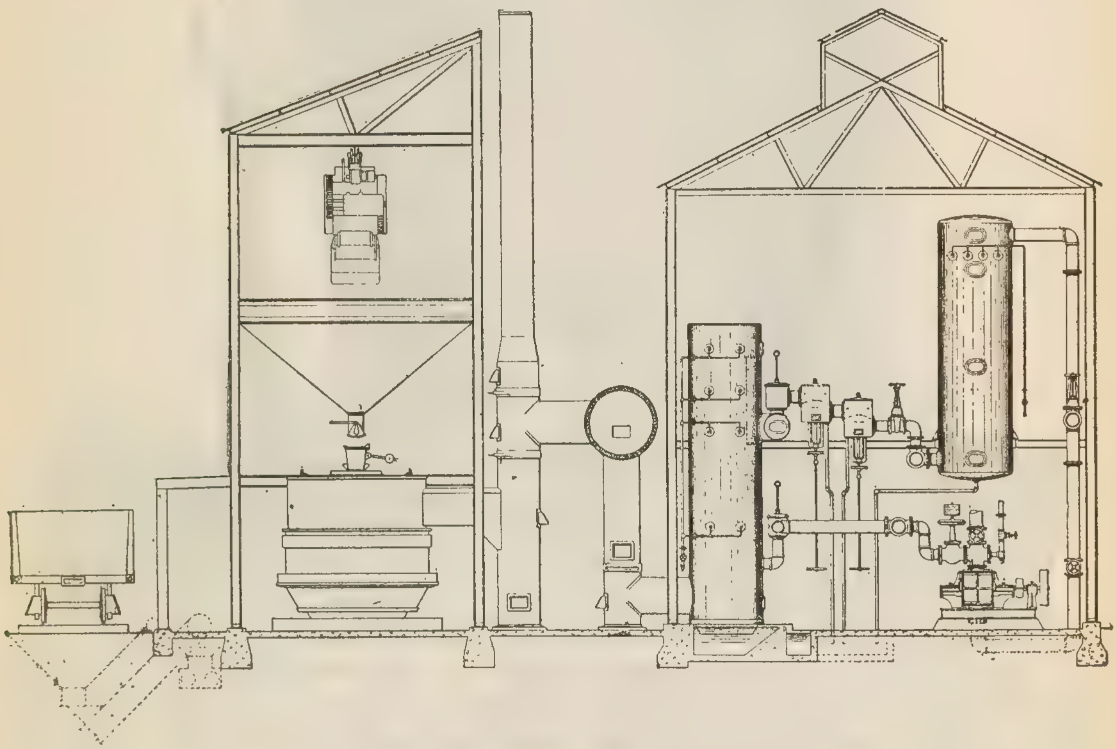
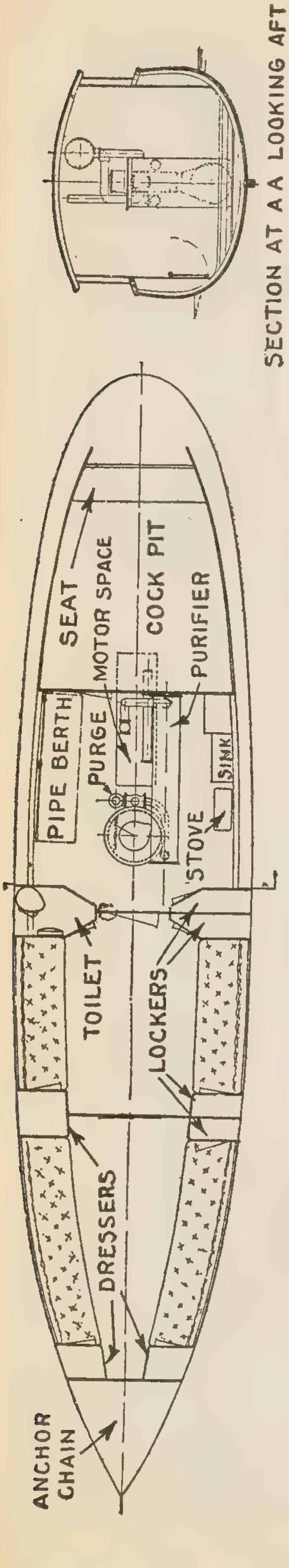


FIG. 8,979.—Gas Plant in connection with a large bituminous producer installation.

further purified by the removal of any tar like substances, sulphur, or ammonia which it might contain, prior to its introduction into the purifier where the purifying operation is completed.

From the purifier the gas passes into the holder which stores up a supply sufficient for starting and for running several minutes, its chief purpose



FIGS. 8,980 and 8,981.—Plan and sectional view of a cruiser showing installation of marine producer plant and engine.

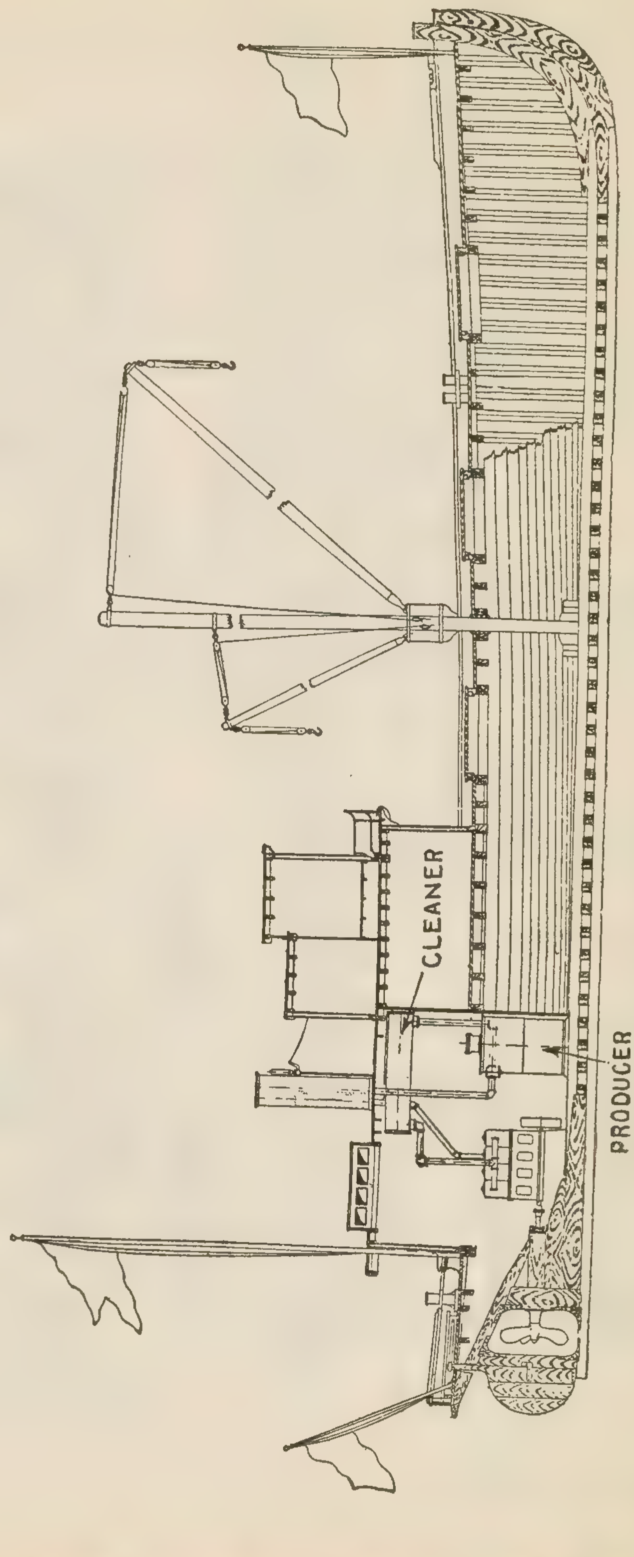
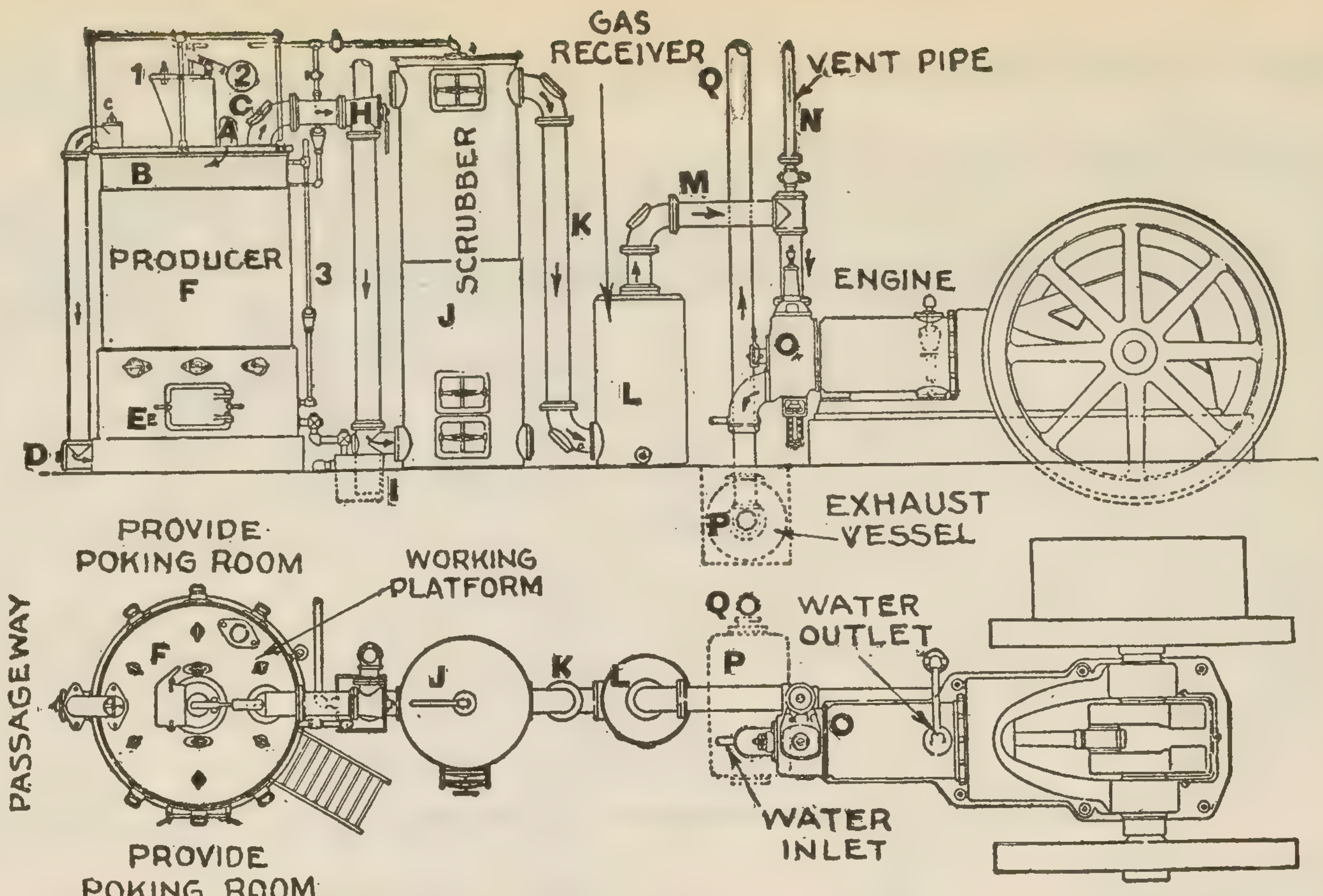


FIG. 8,982.—Sectional view of 115′ × 24′ freight boat with 150 *h.p.* producer plant showing general arrangement of the apparatus and low center of gravity.



FIGS. 8,983 and 8,984.—Elevation and plan of Otto suction gas producer plant. ***It consists of,*** the producer proper F, scrubber J, gas receiver L, and engine O, all connected by piping. ***In operation,*** the piston of the engine moving outward creates a partial vacuum in the entire gas making apparatus and sucks air into the producer through inlet A. The air passes through the vaporizer B, where it is enriched with water vapor, then through pipes C and D, to the ash pit E. At point C, there is an opening through which dry air can be admitted to the mixture going into the ash pit. From the ash pit E, the air is drawn up through the fire F, then through pipe G, three way cock H, and water seal I, to the scrubber J. From the scrubber it passes through pipe K, to bottom of gas receiver L, then out the top through the pipe M, to the engine cylinder O. Pipe N, is a vent pipe which is used as an outlet for the gas just before the engine is started. The gas reaching the engine is drawn into the cylinder, where it is

being the regulation of pressure and variations in the consumption and mixture of gases.

Suction Gas Producer System.—The operation of a suction gas producer system depends upon the sucking action of the engine piston during its forward or charging strokes, which action tends to draw the air supply through the fuel bed of the producer, and the gas generated into the engine cylinder.

In fig. 8,985, which shows the general arrangement of the various adjuncts of a suction system, A, represents the *producer;* B, the *evaporator;* C, the *scrubber;* and D, the *receiver*. The operation of the system may be described as follows:

FIGS. 8,983 and 8,984—*Text continued.*

mixed with air, which is also drawn in by the suction of the piston. On the next inward stroke of the piston the mixture is compressed and then ignited by an electric spark. This burning mixture then expands and forces the piston outward on the power stroke. Again moving inward, the piston forces the burnt gases out into the exhaust vessel P, and then to the atmosphere through pipe Q. ***In charging,*** coal is put in through a charging hopper shown in the illustration at 1. This hopper is closed to the producer while being filled with coal, then is closed to the atmosphere by an air tight door, while the coal is admitted to the fire pot by opening a seal worked lever by 2. The producer is a heavy steel jacket, provided at the bottom with grates, and lined with fire brick. Resting at the top of the producer is the evaporator B, which is a cast iron water vessel of circular cross section. The use of this water filled evaporator is to keep the top of the producer cool for comfortable working, and to provide the water vapor which is mixed with the air supply, and drawn up through the ash pit and fuel bed. The water vapor is mixed with the air primarily to increase the heat units of the gas by the additon of hydrogen. It also prevents clinkering of the fuel, and keeps the fire cooled down to the proper temperature. The mixture of air and water vapor passes up through the layer of ashes resting directly on the fire grates, into the fire zone where it passes through a bed of red hot fuel. Here the mixture is broken up by the heat, and various chemical reactions take place in different layers of the fire pot above the grates, until finally we have coming out of the producer at G, a gas containing about 25 per cent. of carbon monoxide, and 16 per cent. of hydrogen which is the real producer of gas. This gas has a heating value of approximately 140 heat units per cubic foot. The hot gas before passing out of the producer passes under and around the water contained in the evaporator B, adding to the heat necessary to produce the water vapor. The gas in going through the scrubber, which is merely a steel cylinder partly filled with coke, is thoroughly cleaned from all impurities and foreign substances. Cool water is constantly sprayed down over the coke by the sprinkler shown at 4 in the illustration, and the gas coming up is forced by the coke to follow a crooked passage, bringing it in close contact with the water. When the engine is stopped the gas from the producer is shut off by a three-way valve H, which simultaneously opens the connection to the smoke pipe and the atmosphere. The fire is then kept alive by the natural draught, and the process of gas making can be resumed within a short time by a blower, provided for the purpose of starting or reviving the fire. The pressure in every part of the apparatus, while the engine is runnng, is always below that of the atmosphere; consequently, no leaks of gas to the outside are possible. A new fire requires about thirty minutes' blowing, while after a shut down over night, ten minutes' blowing is sufficient to produce gas of proper quality for starting the engine.

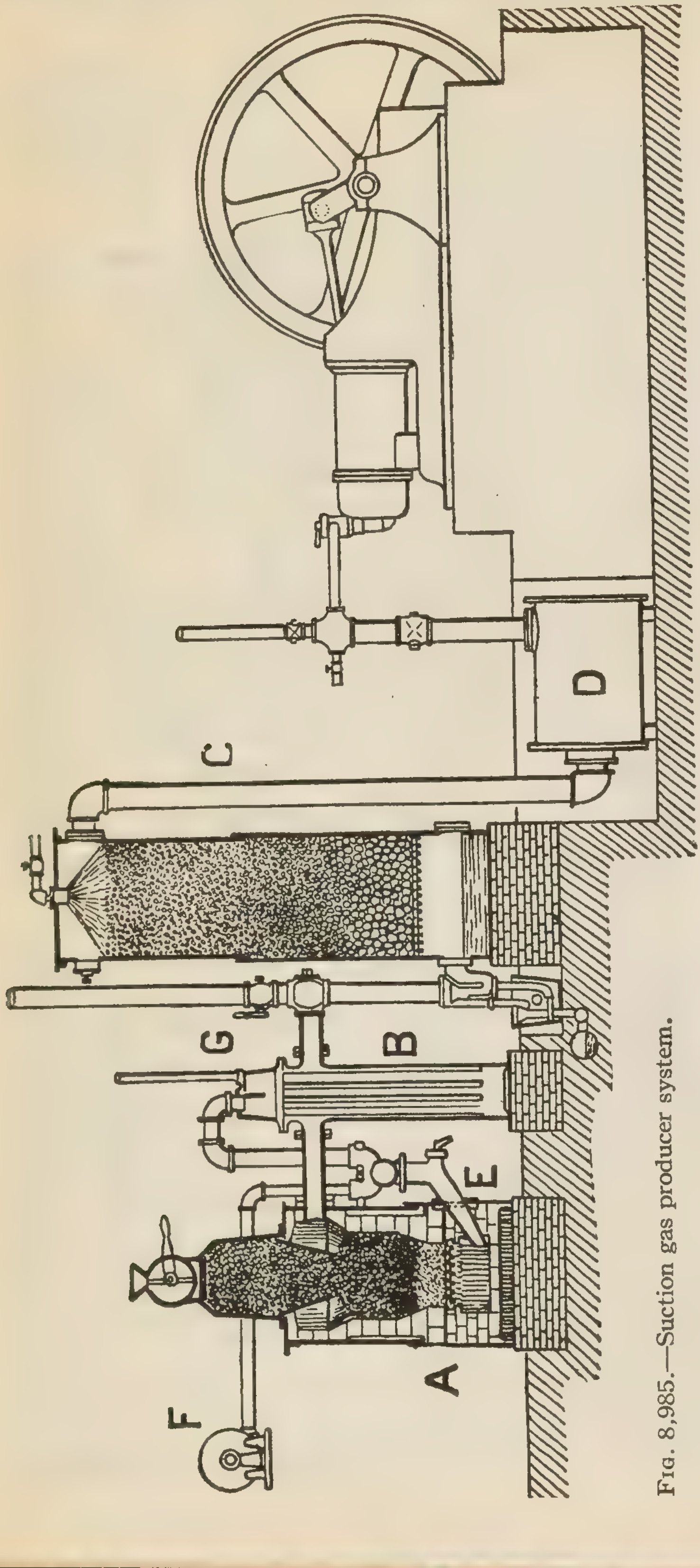


FIG. 8,985.—Suction gas producer system.

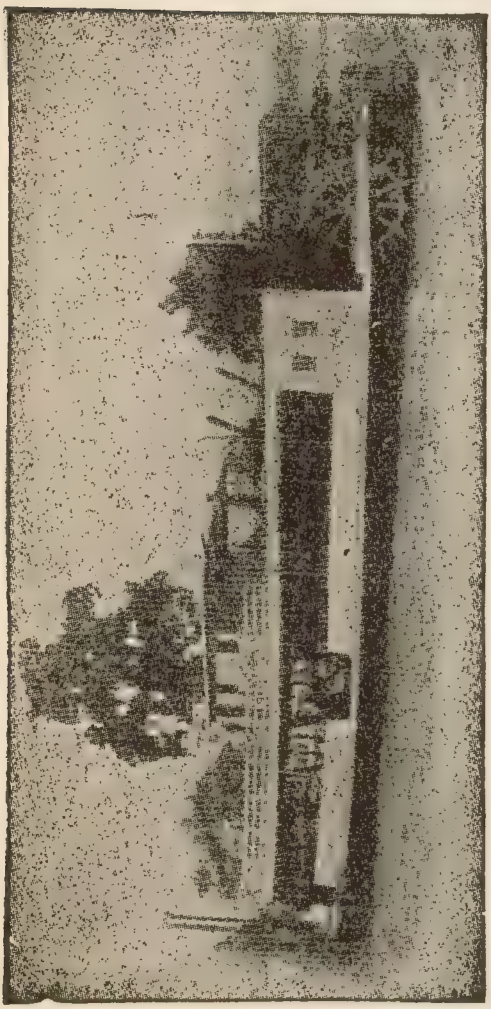
The gases generated in the producer pass through the evaporator, which is practically a small multitubular boiler, and furnish the sensible heat required for evaporating the water. The resultant vapor is conducted to the ash pit of the producer through the pipe E, by the sucking effect in the producer, while the gas passes from the evaporator to the scrubber filled with coke.

As the gas rises through the interstices of the coke, the washing water descends and not only takes up and removes the dust brought over by the gas, but also cleans it of ammonia and other impurities which have a tendency to combine readily with water. From the scrubber the gas passes to the receiver or *suction box*.

The diameter of the receiver being relatively much larger than that of the suction pipe of the engine, the strokes of the engine piston do not therefore cause pulsations between the receiver and the producer.

The producer is usually provided with a charging hopper capable

FIG. 8,986.—Light draught freight boat. Exterior view showing general appearance of the boat.



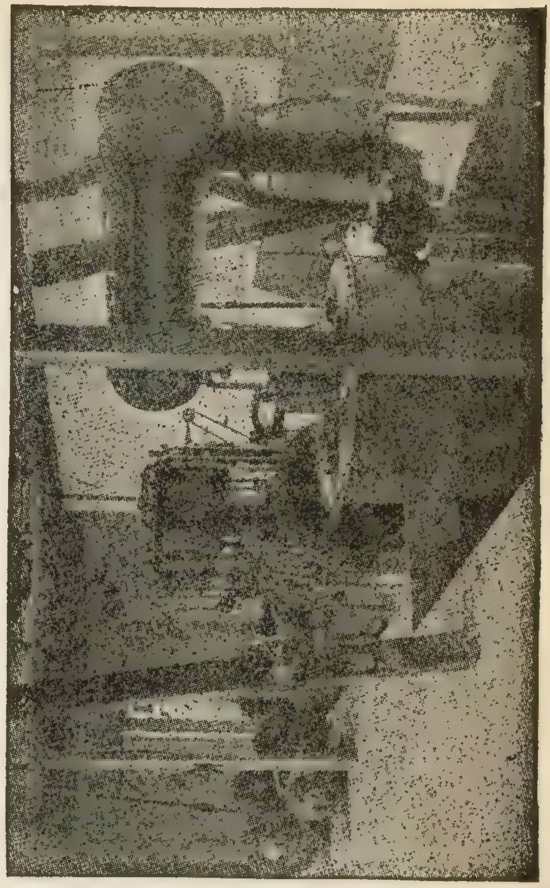


FIG. 8,987.—Light draught freight boat Interior view showing power plant. ***The boat*** is 114 ft. 6 in. overall length, 23 ft. 2 in. beam, and 3 ft draught. Equipped with 75 *h.p.* Marine Producer Gas Power Co. producer Speed 8 miles per hour.

of holding enough fuel for several hours' operation, in the smaller sizes, and allows the admission of fuel to the combustion chamber without permitting access of air thereto during the charging operation.

In operating, a fire is kindled upon the grate, the fuel bed built thereon, and the air necessary for starting combustion supplied by means of a hand or belt driven *fan*, F. The poor and lean gas producer at starting is first allowed to escape into the open air through the *vent pipe*, G, until the test cock shows that good gas is being produced. The pipe, G, is then closed and the scrubber and receiver are brought into the gas circuit. The engine is now put in operation and as it thereafter performs the function of the fan, the latter is stopped, the operation of the entire system becoming automatic.

CHAPTER 134

Gas Machines

The term *gas machine* means *apparatus designed to make gas from a liquid instead of a solid.*

Gas from Naphtha.—In the early methods the production of gas from naphtha has been left mostly to chance and favorable conditions; the methods employed have been to expose naphtha in large quantities, with abundance of heat and air supply, whereby the richest in volatility of the naphtha would be absorbed freely by the air supplied and the denser portions of the naphtha be left incapable of volatization except through large heat exposure; no accuracy in quality of the gas has been inevitably the result, sometimes a supersaturation of the air, thence through all varying degrees of mixture down to a gas of very thin quality.

The shortcomings of the early machines have been overcome with the result that satisfactory gas is now easily made from naphtha. Approved apparatus now performs its functions of compounding the air and naphtha in defined proportions, produces in quantities to exactly meet the current demand for gas; it makes no more nor less than for the moment's need, therefore does not have any stored gas, being responsive and alert to the needs of the moment, as the lungs in the animal anatomy are attuned to quick or slow action, responsive to extreme activity or to repose, and for nothing more than the passing moment's need.

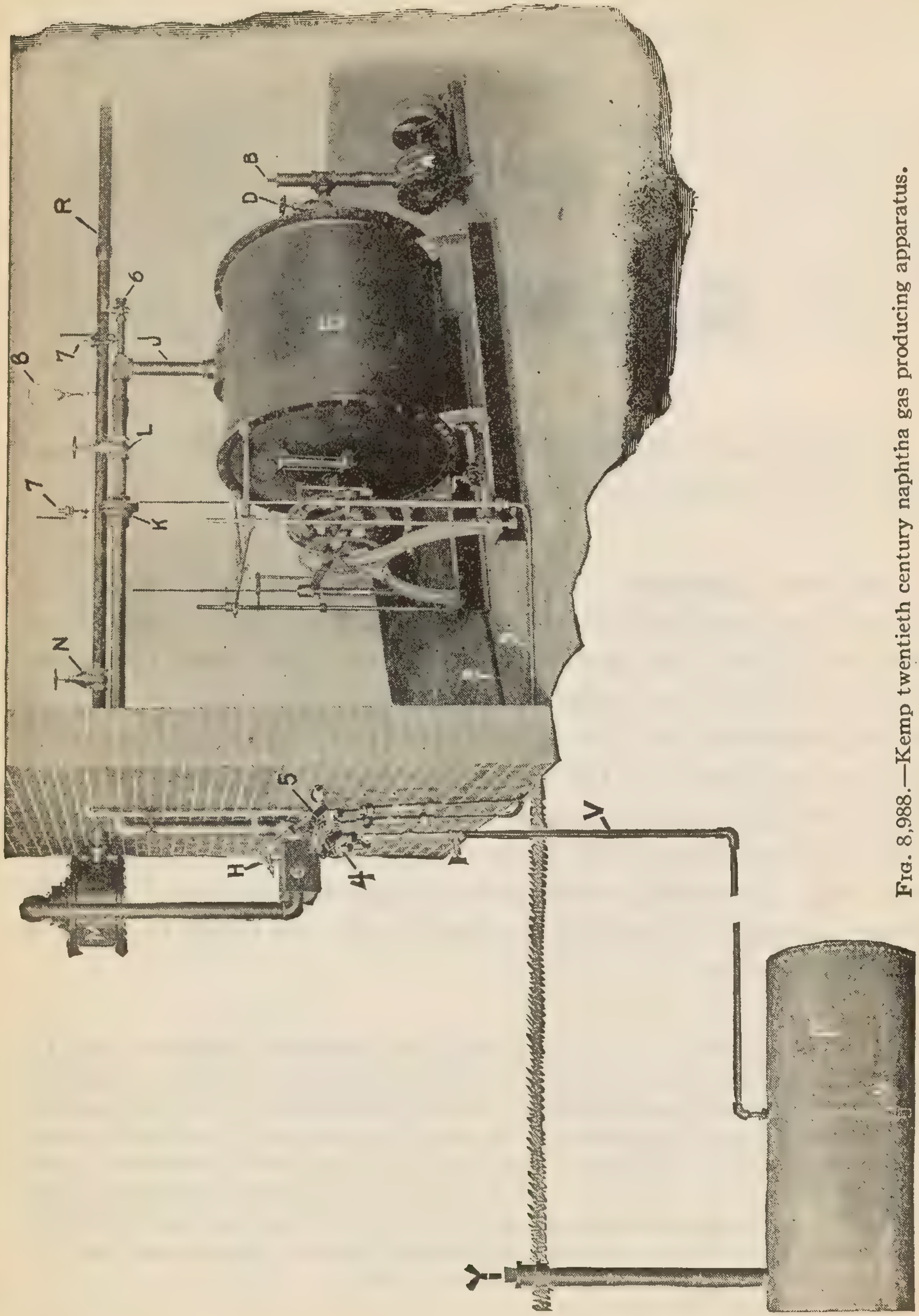


FIG. 8,988.—Kemp twentieth century naphtha gas producing apparatus.

The apparatus is automatic and there is no necessity for an engineer's attention or visit to it except for an oiling once in a few days, which is the main attention required.

The following description of the Kemp apparatus will clearly illustrate how gas is made from naphtha.

Fig. 8,988 shows the machine installed in a building. Inside of the building are the air blower A, and meter E, all other parts with exception of storage tank, are located outside of building, but close to the building wall. A, is a positive pressure blower which will maintain both volume and pressure, has both tight and loose pulleys. B, is a blow off valve by which the surplus air escaped, and is weighted to give the desired pressure, usually one pound to the sq. in. This valve is so constructed as to be very sensitive and will maintain a perfectly even pressure of air at all times. E, rotary meter; the function of which is to measure the air which passes through it and to pump the proper amount of naphtha to mix with that air. It is very accurate. G, converter in which the gas is generated. It has a partition separating it into an upper and lower compartment, heated by steam passing through the lower compartment, cast in one piece, consequently is not affected by expansion and contraction. (Converters of the very large machines are made of wrought iron); M, back fire preventor; F, storage tank to which the naphtha is almost completely confined, usually buried in the ground; D, L, and N, gate valves; C and K, special check valves; 1, 2 and 3, mercury naphtha pumps; 4 and 5, naphtha check valves; 7 and U, mercury pressure gauges; 8, test burner.

Air from the blower A, enters the meter E, at the back, passes through the meter, and is conducted by the pipe J, to the outside of building, where it enters the converter G, at the side.

In passing through the meter the air causes the shaft of meter to revolve, a definite amount of air being required to pass through to give the shaft a complete revolution. Each revolution of the shaft by means of the mechanism attached thereto, operates the plungers in the mercury in the vacuum cylinders to rise and lower, drawing the naphtha from storage tank F, through the one half in. suction pipe and delivering it to the converter G, through the delivery pipe H. The naphtha pumps work alternately, one drawing its supply of naphtha while the other is discharging its supply into the converter, consequently, there is no pause in the delivery, or the delivery is not intermittent; the naphtha going into the converter in a steady stream, or drop at a time, in quantity just sufficient to supply the gas demand of the moment.

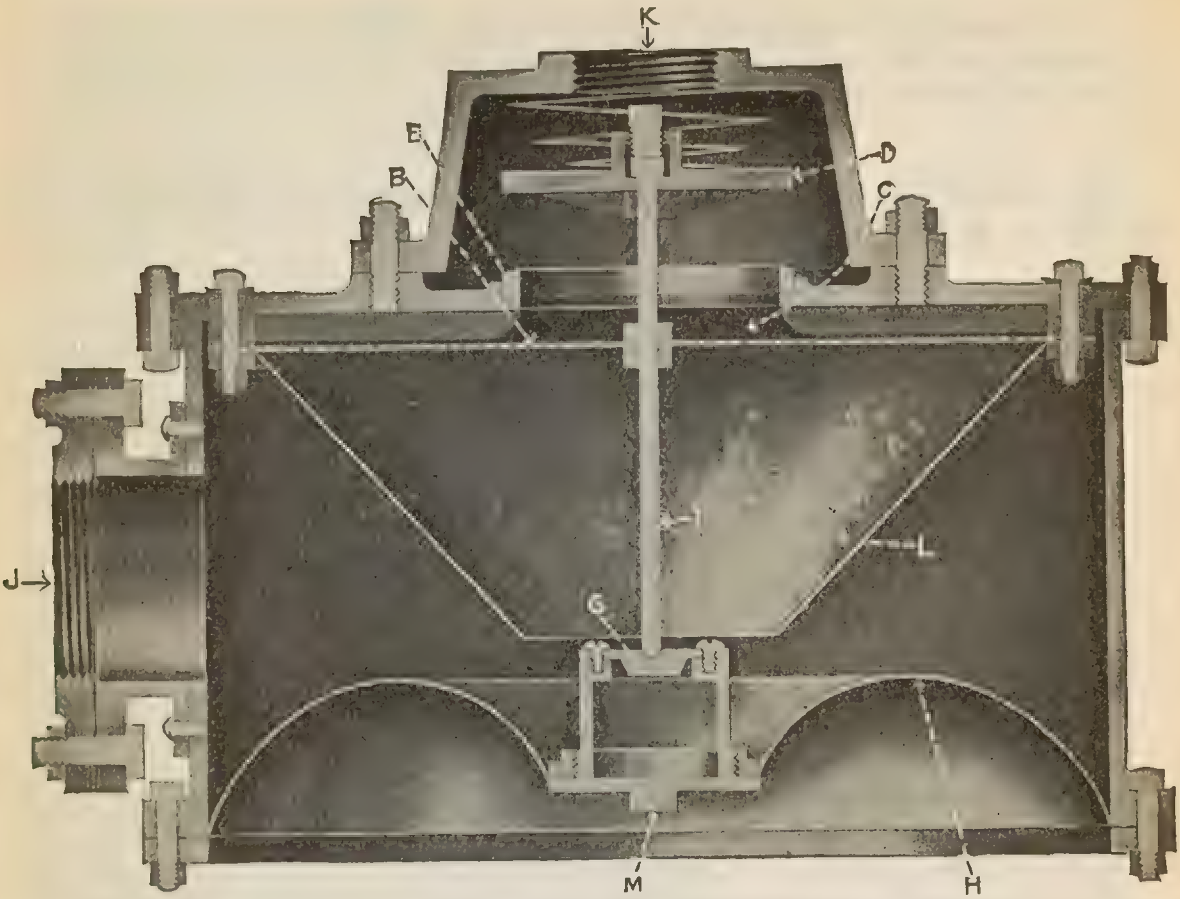


FIG. 8,989.—Kemp twentieth century back fire preventer. As the Kemp gas machine combines air and naphtha in a predetermined ratio carrying the gas very thin for economy a back fire preventer is employed which cuts off the gas current in case of a back fire in the gas main. The back fire preventer is placed in the gas main outside of the building between the converter and the points of distribution. ***Its operation is as follows:-*** The gas enters the preventer at K, passes around the valve D to C, where a large surface is provided for it to pass through the disc B, which is a metal plate full of very fine perforations, then the gas flows downward and under the deflector L, to the gas outlet J. The valve D, is seen maintained off its seat E, and with a compressed spring at its top, a pin driven across holds against the upper end of this spring, the valve steam I, passes through the perforated disc B, and rests on a bridge G. This bridge is made of a metal fusible at a low temperature, and is attached to a plug M, which screws into a threaded flange made in the center of the convex bottom H. The bottom H, is made of sheet metal, thin and light compared with the body and top of the back fire preventer. In case of an explosion, the yielding bottom H, is forced outward, carrying with it the fusible bridge G. The valve stem thus losing its support, the valve D, is quickly seated; its own weight or gravity causing it to seat, aided by the compressed spring and the pressure of gas above the valve. Any one of these three forces being sufficient, but when in conjunction, a triple assurance of a prompt closing off of the gas—the perforated disc B, prevents any flame passing through it, and is braced above so that the shock of an explosion of the gas will not break it. In case of an ignition of the gas, but no explosion, the heat from the burning gas quickly melts the fusible bridge G, thereby enabling the valve to seat. The purpose of the deflector is to cause the heat to pass in close proximity to the bridge G, insuring its quick melting.

The naphtha enters the converter at the top, drops on the heated partition and is completely vaporized. The air which passes through the meter (actuating the pumping mechanism which delivered the naphtha to the converter) enters the converter at the side and combines with the naphtha vapor, resulting in an ideal fuel gas of high heating efficiency. This gas passes through the back fire preventor M, and is conducted by the gas main R, to the burners. The quality of the gas is controlled by the stroke of the mercury pumps.

To make the gas richer, it is simply necessary to move the radial clamp nearer to the shaft, thereby increasing the stroke of the pump plungers, and increasing the feed of naphtha.

In other words, changing the ratio of air and naphtha entering the converter G, or mixing more naphtha with the air that has passed through the meter E. Reverse action reduces the stroke of the pumps, reducing the amount of naphtha that is mixed with the air, making the gas thinner. Every time the shaft of the meter E, makes one revolution it means that a definite amount of air has passed through the meter to the converter G, and that each mercury pump has delivered a definite amount of naphtha to the converter.

When the machine is once installed and adjusted to produce the desired quality of gas, no further adjustment is necessary. The same quality of gas is maintained whether there is but one in. of naphtha in storage tank or the tank is fully charged, whether few burners are in operation, or the machine is run to its utmost capacity, and whether the gas service is required for but a few minutes at a time, or day and night for years without cessation.

Naphtha is difficult and almost impossible to confine by packing, cut leathers, etc. The mercury naphtha pumps have no packing or cup leathers.

It is impossible for the naphtha to leak past the mercury. The pumps are absolutely tight.

NOTE.—***For domestic purposes*** the type Kemp apparatus used embodies the same principles as the machine described in this chapter, but is arranged to be operated by a weight and a compound system of pulleys reeved with a wire cable, which winds upon a spool on the apparatus, or to be automatically operated by a water service. The gas produced by this apparatus makes brilliant illumination with incandescent burners, serves gas ranges for cooking, etc. and in gas grates and gas heating stoves.

When the column of mercury in vacuum cylinder lowers one in. or six ins. it is bound to draw up one or six ins. of naphtha, and when the mercury column rises it is bound to discharge that naphtha into the converter.

Note that when naphtha enters the converter, air goes with it, and in exact ratio to it, as the air must pass through the meter E (operating the mercury pumps) for either air or naphtha to enter the converter.

CHAPTER 135

Gas Meters

Meters.—The gas used by every customer is measured by a meter. The principle of measurement employed in meters is *the admission of gas into chambers, the volume of which is accurately known, a registering mechanism being provided to record the number of times the chambers are filled and emptied.*

The first dry gas meter was developed by John Malam in 1820. It consisted of six diaphragms radiating from a hollow shaft inside of a tin case and accurately controlled by a valve resembling the rotary valve used in some present types of meters. It was never actually used. A one diaphragm meter was invented by Bogardus in 1833 and in 1836 he developed a two diaphragm meter. Neither of these two types of meters was used to any extent although much money and labor were spent in attempting to perfect them.

NOTE.—***The first practical gas meter*** was made in England in 1815 by Samuel Clegg. ***In operation*** it was similar to wet meters of the present day, being a wet type rotary drum meter. It was improved by John Malam in 1817 and still further improved in 1820 by Samuel Crosby. One writer has stated that "To these three men the gratitude of the gas engineers of all times should be accorded for the reason that through their efforts the meter was developed as a practical registering machine, enabling the growth of the gas business from a condition of almost complete failure to its present enormous development."

NOTE.—When manufactured gas was first produced commercially in England, it was sold on the basis of estimated number of ft. per hour for each burner. Such computation was obviously not only unsatisfactory, but unprofitable. The result was the diligent search for a means of ascertaining the exact amount used by each customer. It was not until Clegg in 1815 brought his wet meter to a state of approximate perfection that the gas business became commercially safe and profitable. Clegg's wet meter turned the uncertain fortunes of the experiment of manufacturing gas into a commercial success. This wet meter, with many improvements, and imperfections corrected, is to this day used as a station meter for ascertaining correctly the volume of gas made at the works before it is stored in the holder, for the correct measurement of small volumes in an experimental or laboratory process, and to some extent in England, and the continent as a consumer's meter. It has been largely replaced for the latter purpose abroad, and entirely in this country, by the more convenient dry meter.

Principle of Measurement.—While it is possible for a man to both test and repair a gas meter without fully understanding its principle of measurement and operation, this knowledge is essential to the correct analysis of many meter troubles and is well worthy of the careful consideration of every person working with gas meters. In Forstall's "Manual of Gas Distribution" the principle of measurement of the gas meter is likened to that of measuring a quantity of liquid drawn from a cask, through a spigot, into a quart measure, emptying the quart measure each time it is filled through a cock controlling an opening in its bottom, and then counting the number of measures emptied, to determine the quantity of liquid drawn from the cask. To insure accurate measurement, it is necessary to fulfill the following conditions:

1. The measure must accurately contain one quart.
2. While the measure is being filled through the spigot, no liquid must be allowed to escape into the receptacle for the measured liquid.
3. After the measure has been filled, the spigot must be completely closed before the measure starts to empty.
4. An accurate account must be kept of the number of measures filled and emptied.

In the gas meter, instead of one measure being alternately filled and emptied, four of these measures are operating simultaneously—some filling while others are emptying, but always fulfilling the above conditions. This insures a uniform delivery of gas instead of an intermittent one, such as would result if only one measure was employed.

In the meter, each of these measures is the difference in capacity of the diaphragm at the end of its filling and emptying stroke. These strokes can be accurately adjusted to make the difference in diaphragm capacity equal to the standard liquid measure. To measure the gas passed, it is then necessary to have a mechanism so constructed, as to register the number of times each measuring chamber is filled and emptied in terms of cu. ft. This is accomplished through the index mechanism operated from the crank by the movement of the diaphragm.

In 1844 Messrs. Croll and Richards invented a two diaphragm slide valve meter that was accurate in registration and regular in its action. The essential ideas of construction and principle of this meter have remained unchanged to the present day. Several years later this meter was perfected by Thomas Glover and is generally referred to as the "Glover two diaphragm slide valve meter" or tin case meter. The construction of this meter is shown in figs. 8,990 and 8,991.

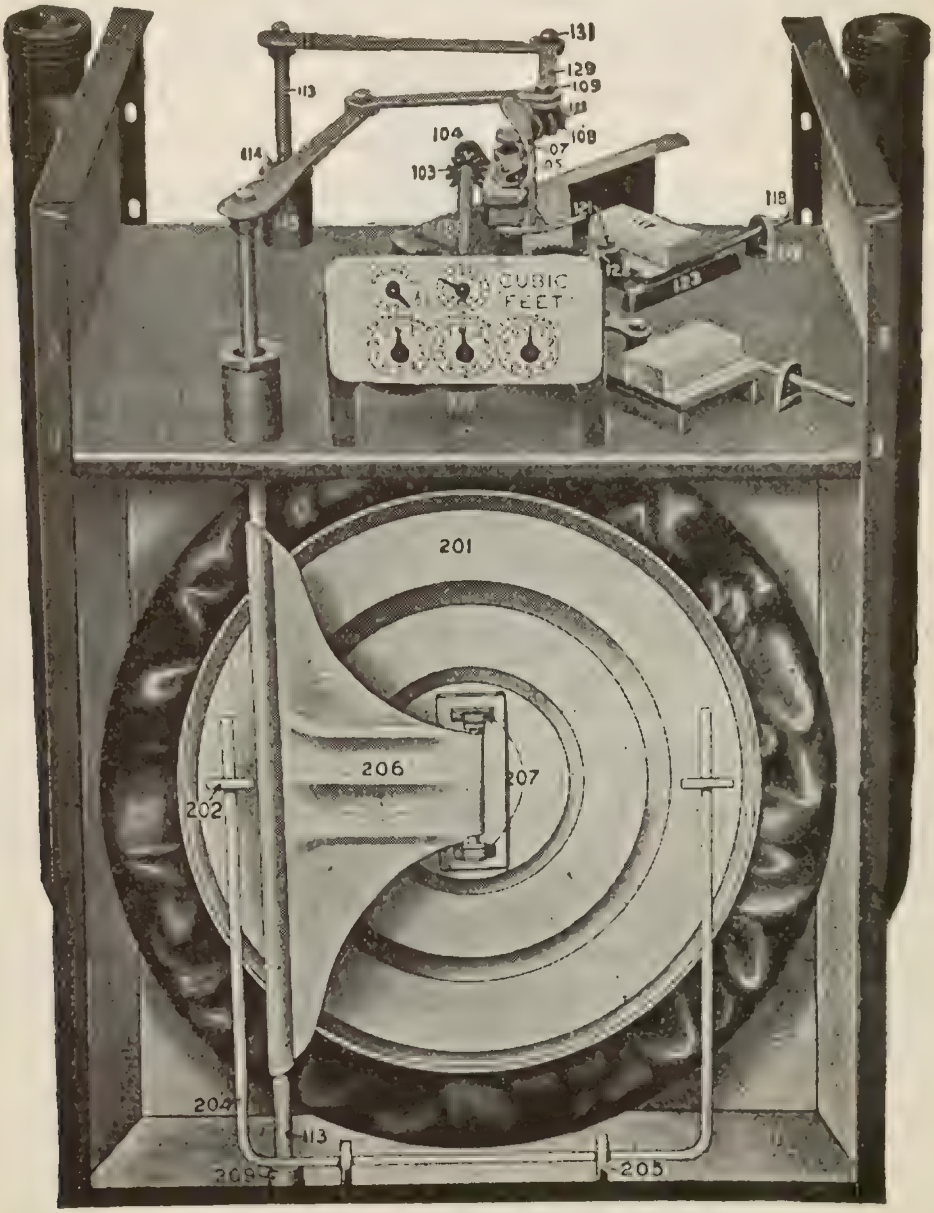


FIG. 8,990.—Side view of tin case meter. ***The parts are***—201, diaphragm disc; 202, disc bracket or eye; 203, diaphragm; 204, guide wire; 205, boot; 206, flag complete; 207, flag

The motive power that actuates the meter is the difference in pressure of the gas at the meter inlet and outlet. No motion can take place unless this pressure difference exists. As the valves are at right angles to each other and connected to a single crank, it is evident that there can be no position when both valves are on dead center and that as soon as the pressure at the meter outlet is reduced by turning on some gas burning appliance, the gas pushes one or the other of the two diaphragms in or out, depending on which port happens to be open to the outlet at the time this gas is turned on.

Assume that the gas is turned on when the valves and diaphragms are in the relative positions shown in fig. 8,993. The back chamber is

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Fig. 8,990—*Text continued.*

bracket or carriage. ***In construction,*** the case is made of a number of tinned iron plates soldered together to form a nearly rectangular box. A U shaped tin tube is soldered vertically in the center of each side and a threaded brass screw is soldered into the top of each of these tubes. The meter is divided internally into three principal compartments by a horizontal and a vertical partition. The horizontal partition is called the table and the space above it is called the gallery. The space below the table is divided into two equal compartments by the vertical partition which is placed midway between the front and back of the meter. A small gas tight compartment, called the valve chamber, is constructed in the gallery and contains the valves which control the passage of the gas in and out of the compartment below the table. In each of the lower compartments or chambers formed by the vertical partition is a flexible leather diaphragm, mounted centrally on the partition. Four measuring chambers are thus formed—the interiors of the two diaphragms and the space in the diaphragm chamber outside of the diaphragms. The diaphragms are supported by arms or flags attached to the diaphragm discs by the diaphragm carriages. The flags are in turn attached to vertical flag rods. The lower ends of these rest in bearings soldered to the bottom of the meter. The upper ends of the flag rods extend into the gallery, through stuffing boxes in the table. The flags not only support the diaphragms with their discs, but guide them in their inward and outward travel, so that they always move in the same horizontal plane. Disc guide wires supported from the bottom of the meter and sliding in guides on the diaphragm discs still further guide the movement of the diaphragm by keeping the two guide points moving laterally at the same speed. The flag rods are connected by jointed arms to a tangent post mounted on the tangent arm. This tangent arm is rigidly attached at right angles to the top of the vertical crank shaft, which passes through the bridge and center stuffing box into the valve chamber. The two slide valves, which control the flow of gas in and out of the diaphragms and compartments, are attached by means of short valve arms to the single throw crank, as in fig. 8,991. In each valve seat are three ports. The center port communicates with the meter outlet through the forked channel. The one nearest the diaphragm channel, and the one farthest from the crank communicates with the diaphragm compartment. Their arrangement can be more readily understood by noting fig. 8,992. A worm or spiral mounted on the vertical crank above the valve chamber and below the tangent turns a gear mounted on a horizontal shaft which drives the recording mechanism or index.

connected through the port Q, of the back valve V_1 to the meter outlet O. The back diaphragm is also open to the pressure of the inlet gas.

The gas entering the back diaphragm pushes it out, forcing the gas in the back chamber through port Q, of the back valve V_1, to the meter outlet O. While this diaphragm movement is taking place, the back valve V_1 is moving to its dead center position and the front valve V, is moving to the

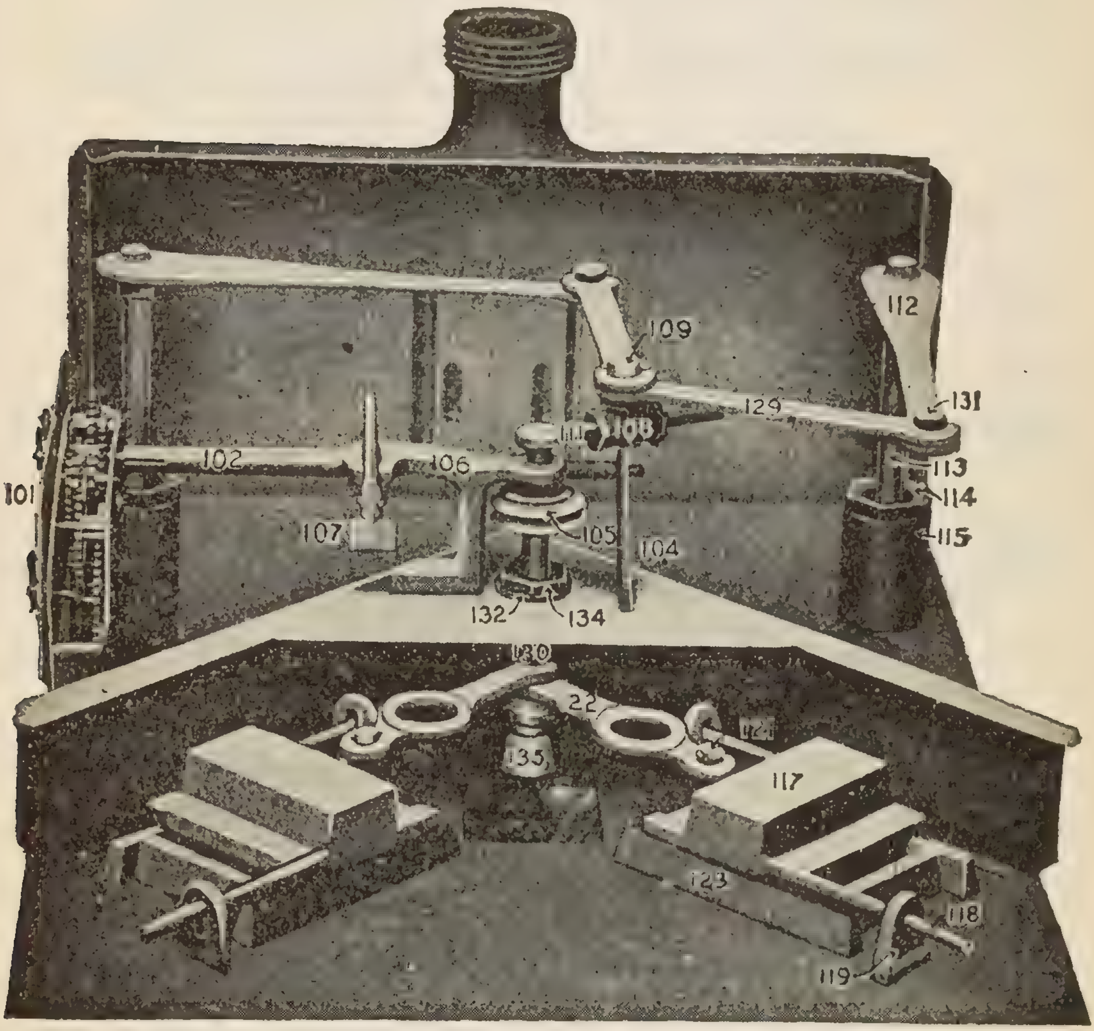


FIG. 8,991.—Top view of tin case meter. ***The parts are:*** 101, index; 102, index axle; 103, axle wheel; 104, axle rest; 105, spiral or worm; 106, crank frame; 107, click; 108, tangent nut; 109, tangent post; 110, tangent post pin; 111, tangent arm; 112, long flag arm; 113, flag rod; 114, stuffing box cap; 115, stuffing box; 117, valve cover; 118, valve cover wire; 119, valve guide; 121, valve wrist; 122, valve cover arm; 123, valve seat; 120, short flag arm; 130, crank; 131. flag arm rivet: 132, crank box; 134, crank box cap; 135, crank stop.

end of its out stroke, admitting gas to the front diaphragm. The relative position of the valves are shown when the back valve V_1 has reached its dead center position, fig. 8,994, shutting off the back diaphragm from the inlet gas and the back chamber from the outlet. While this has been occurring, the front valve V, has moved to allow inlet gas to enter the front diaphragm, forcing the gas in the front chamber through the front valve port Q, to the meter outlet O. Thus, when the back valve is in a position that prevents the back compartment supplying gas to the meter outlet, the front diaphragm is moving outward, forcing the gas out of the front chamber.

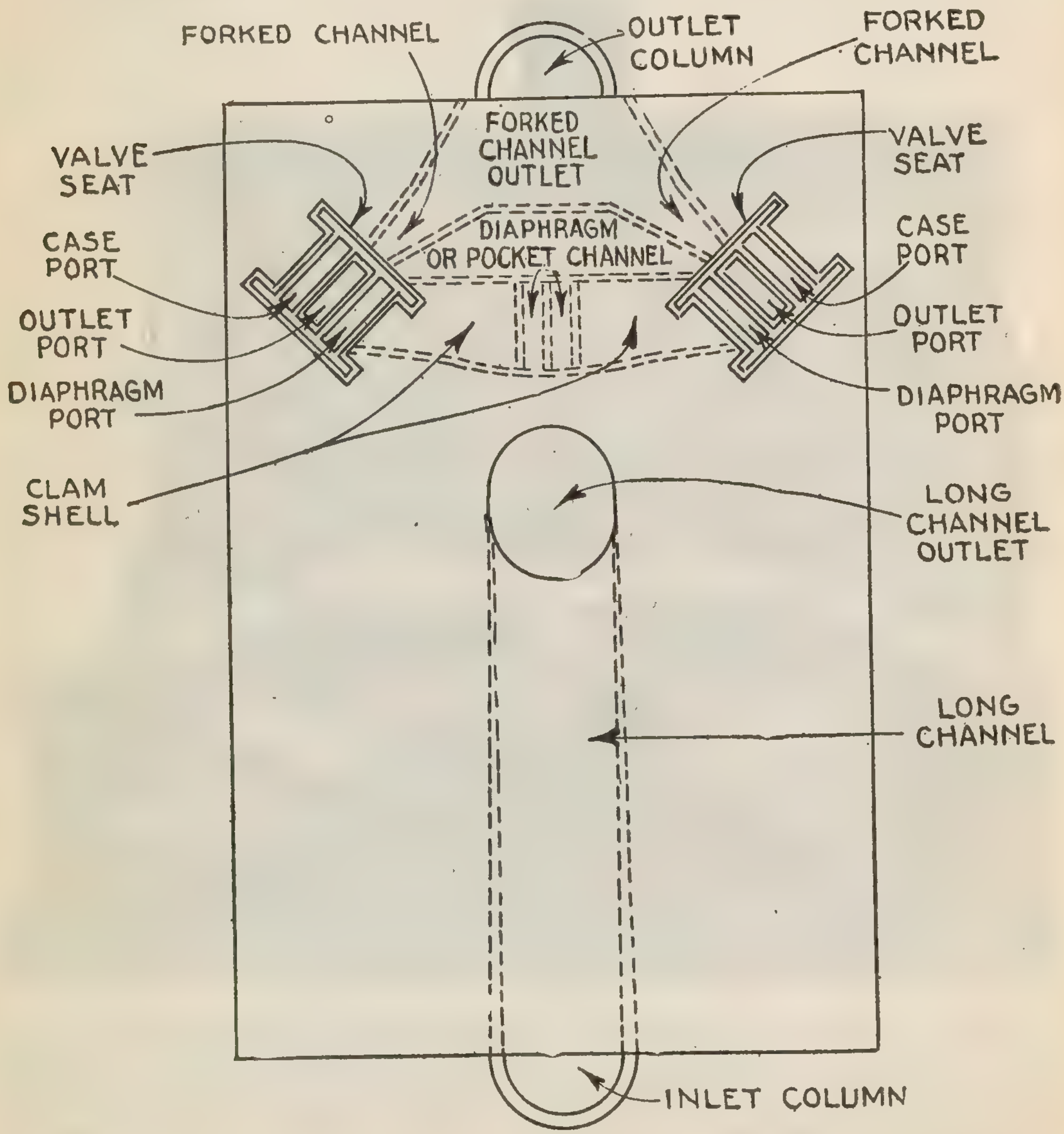
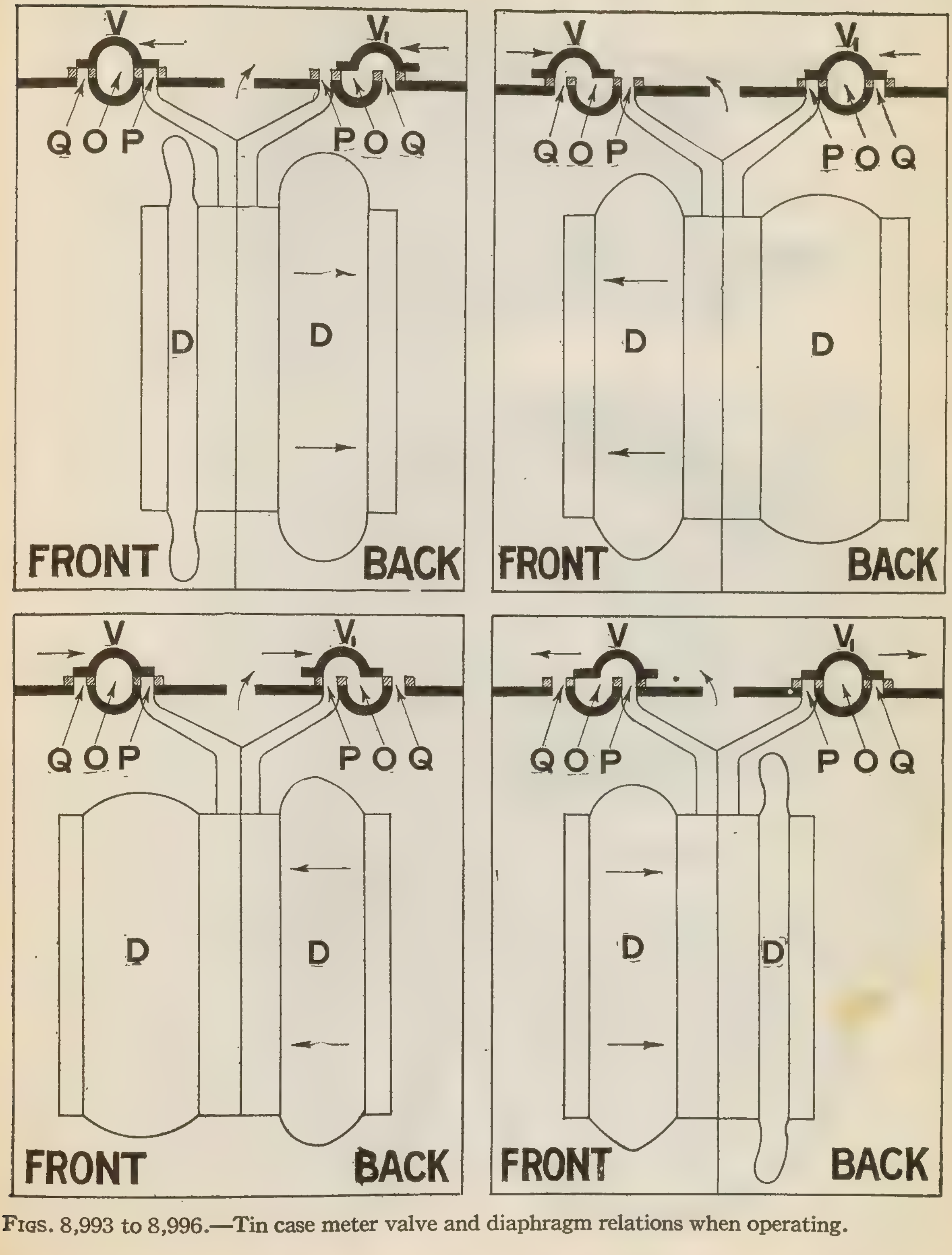
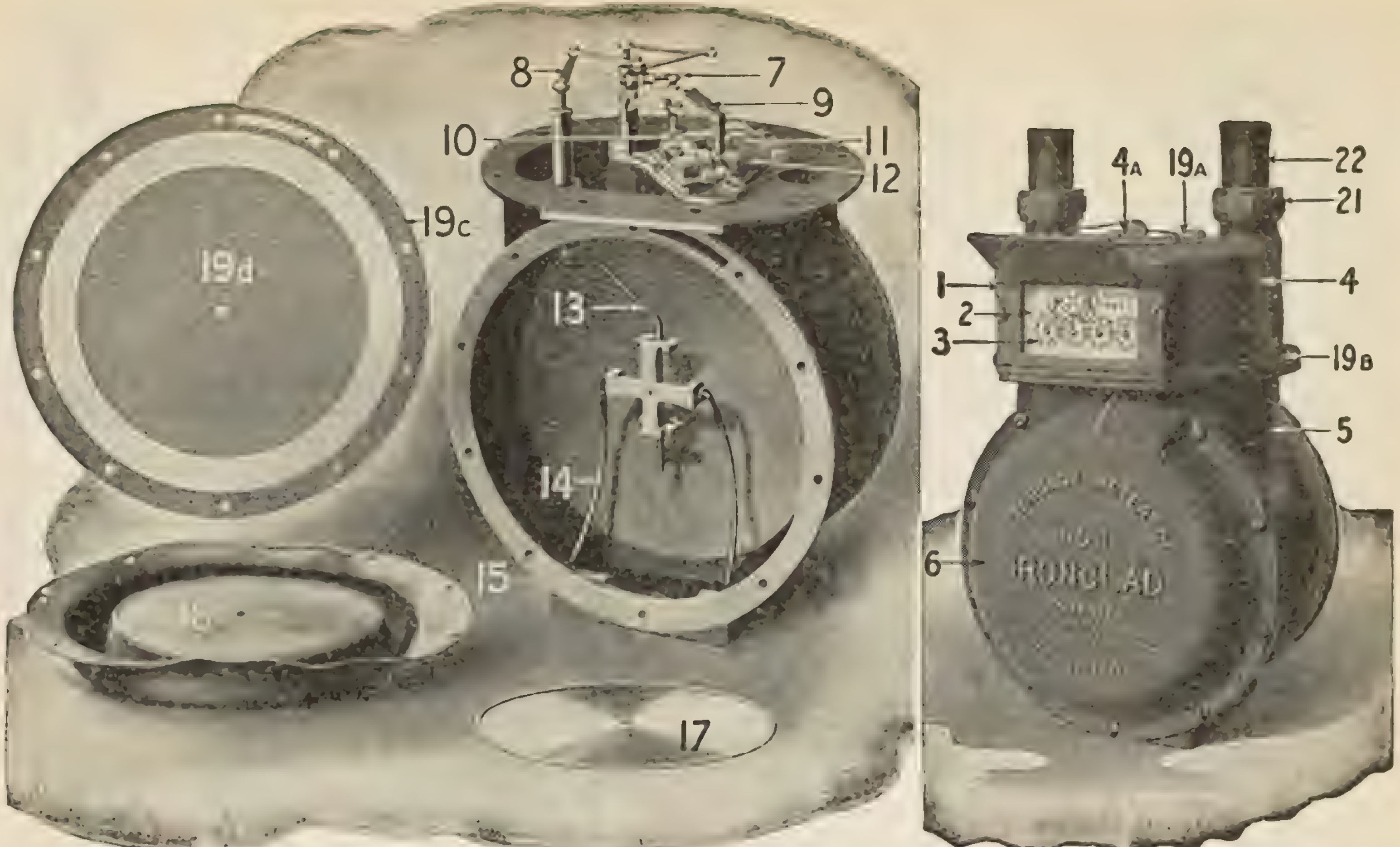


FIG. 8,992.—Diagram showing valve seats and channels of tin case meter.



FIGS. 8,993 to 8,996.—Tin case meter valve and diaphragm relations when operating.



FIGS. 8,997 to 9,001.—Ironclad gas meter. ***The parts are:*** 1, register box and cover; 2, glass; 3, register; 4, case cover; 4A, case cover cap; 5, case; 6, front or back cover 7; tangent or duplex adjustment; 8, flag arm and link; 9, frame; 10, crankshaft, 11, valves front or back; 12, valve seat; 13, flag wire front or back; 14, guide wire; 15, guide wire bearing right or left; 16, diaphragm; 17, diaphragm disc front or back; 19A, case cover cap gaskets; 19B, case cover gaskets; 19C, diaphragm flange gaskets; 19D, diaphgram disc gaskets; 21, union nut; 22, swivel.

Follow this progression to the third position in the cycle of meter action, fig. 8,995. The front diaphragm has filled and the front valve V, has moved back to its dead center position. The back valve V_1 has reached the end of its inward stroke, and the inlet gas is now entering the back chamber, pushing the gas from the back diaphragm through the port P, of the back valve to the meter outlet through O.

Fig. 8,996 shows the fourth position in the cycle. The inlet gas has pushed the back diaphragm to its empty position at which point the back valve V_1, meanwhile has moved in to the end of its stroke and the gas now enters the front chamber forcing the gas out of the front diaphragm.

The next step in the cycle refers to the valve and diaphragm relations shown in fig. 8,994 following each other in the order described above as

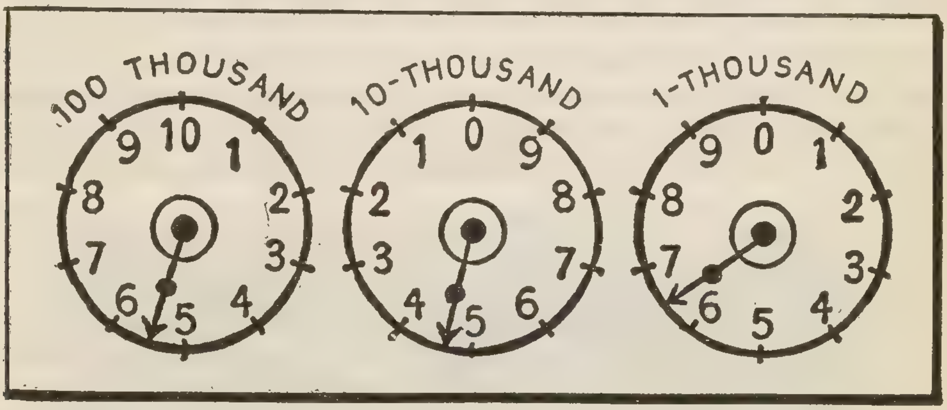


FIG. 9,002.—How to read the meter. ***Rule:*** Begin with the left hand dial, and put down the figure that each hand or pointer has passed, every alternate dial being read in the reverse direction, until the last, or "1 thousand" dial is reached. For this last dial, the rule is: If the hand has not yet gone half way to the next number, the number that has been passed should be taken, or if it be past the middle point, then the larger number should be taken, and if there be any doubt, the larger number should be taken. ***Example:*** The index here shown should read 546. Add two ciphers, thus 54,600. From this, subtract the meter reading at the end of the previous month as shown on the last gas bill, and the result will be the cu. ft. of gas used during the month.

long as the meter outlet pressure is below the inlet pressure. The positions of valves and diaphragms shown in figs. 8,993 to 8,996 are called the points of cut off, when the tangent arm is rotated in a clockwise direction.

Directions for Meter Testing.—In testing meters particular attention must be paid to temperatures. The temperature of the meter, the water in the holder, the air in the room and in the holder should not vary more than 2° Fahr., if so, adjust them either by changing the temperature of the air or water;

if it be necessary to change the water be sure it is thoroughly mixed before testing.

Connect the meter with the holder and test for tightness by allowing enough air to run through to start the meter, then stop the outlet and shut off the holder, noting the pressure on the gauge; after standing 30 seconds, the holder is turned on and the pressure should not drop more than 2/100 of an in. More would indicate a leak or faulty temperatures; if a leak, find it and stop it. Then turn on holder again and run, for small meters, 3's, 5's and 10's, at least half a ft. to starting point, finishing with rate on; for larger meters run from one to ten ft. The legal rate, the one generally used, is six ft. per hour, =one-tenth of a ft. per min., for each light the meter is marked to supply, *i.e.* thirty ft. per hour for a five light.

It is better to start from a side point on the dial than from a top or bottom one. The holder is now set at O, or some chosen point and turned on to the meter until the experiment hand has made a complete revolution, the holder being shut off when the hand reaches the starting point exactly.

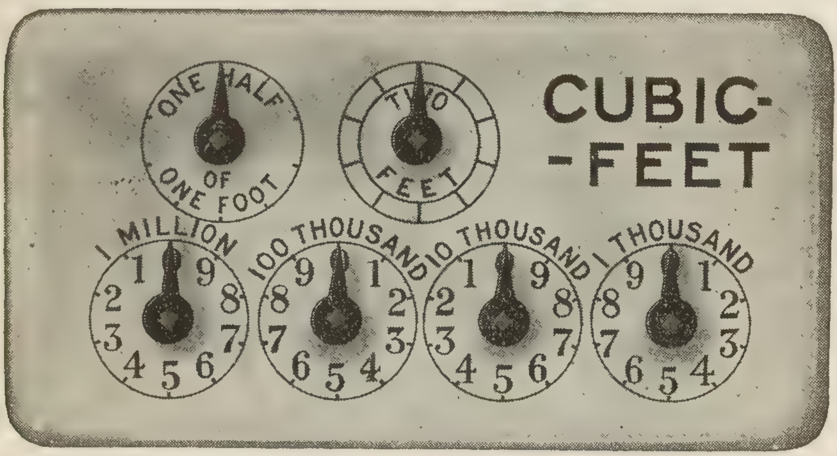


FIG. 9,003.—Dial of Ironclad meter. ***Directions for reading:*** Take the first figure the hand or pointer has passed, first on the circle marked 1 thousand, then the next larger, and so on; the circle "two feet" is called the proving hand, and is used for proving only. The illustration shows a zero reading. ***Example*** in reading:
Assume

On 1 thousand circle	400 cu. ft.
" 10 " "	6,000 "
" 100 " "	50,000 "
" 1 million "	900,000 "
Full reading of indexes	956,400 "

When the pointer is between two figures, take the smaller. It is never necessary to reset the index. When the pointer on the circle of highest denomination has made a complete revolution, all pointers will indicate zero.

The amount of air used in holder is divided by amount registered by meter and the result is in per cents, *i.e.* with a 2 ft. circle the holder indicated 1.95 ft. $1.95 \div 2.00 = .975$ making the meter 2.5% fast. The holders are generally marked to read per cents, directly on two, five and ten ft. runs.

The essence of accurate meter testing lies in temperatures. The holder must be protected from the sun and draughts of air, meters should be kept off the floor and the person making the test should know that the temperature of the meter is the same as that of the holder and room air. During the winter months meters should stay in the proving room 10 or 12 hrs. before being tested.

The foregoing directions however, cover only the legal rate test, which is at the rate of six times the so called meter light. It has been found better practice to test all meters on both the legal rate and the open outlet.

At times a meter will test correctly on the prover for accuracy, and still have an inside leak, either in the valves or diaphragms, and pass an appreciable amount of gas without registration.

Meters that have been in service for a limited period since they were new or repaired, and which do not test correctly, may require only adjustment and no repairs. After the top has been removed, test for tightness by the so called four point test with gas at a pressure not exceeding 1½″. To do this, connect the meter with gas, using on the outlet a bank of burners, or a ⅛″ burner cock.

Purge the meter of the air and light the burner. Disconnect the flag arms and point the tangent in line with the center of one of the valves. The gas in this compartment should burn out quickly and the light thus extinguished. Then move the tangent to the second, third and fourth quarters or points, light the gas and test as above. If the gas go out completely on all four points, this indicates a tight meter. The adjustment of the tangent is all that is required to bring the meter to a correct proof.

A slight change in the accuracy or test of a meter originally correct when placed in service may be caused by a slight bind or drag in the working parts. If the inaccuracy be on the fast side, try the travel or clearance of the diaphragms on all four compartments to see if they be contracted. To do this, disconnect the meter, leaving the inlet and outlet open to the air. Then disconnect the flag arms from the tangent. Inflate the back diaphragm with air, working by hand the long part of the flag arm to a position parallel with the gallery of the meter. Point the short part of the flag arm in line with the tangent. The opening in the short arm which fits over the tangent bat should not travel beyond the bat, but should have such clearance as to allow the diaphragm in motion to make its complete

travel without jumping. Make this test on all four points with the diaphragm inflated and deflated; otherwise the meter will not properly function, and will give an unsteady flow of gas in service. In that event, the back and front of the meter should be removed and the diaphragm carefully re-oiled. If there be much condensate in the diaphragm chamber, better results will be obtained if the meter be permitted to remain open 24 hrs. and the leather thus allowed to dry out before re-oiling.

A dry leather will absorb the oil much better than one which contains more or less moisture. Better results will also be obtained if the diaphragm oil be heated to a temperature of 110° Fahr.

If after removing the top from an incorrect meter and the four point test indicate a leak, the valve enclosure plate should be removed and the valves, channels, and diaphragms tested for tightness. To test the valves and channels, connect the outlet of the meter with either air or gas at not over 1½ in. pressure.

A pressure gauge should be connected between the meter and the stop cock. By watching this gauge as the supply is shut off, a leak will be indicated by a drop in the water column. If the valves show a leak, they should be re-ground and fitted tight. Then remove the valve covers to test the diaphragms, using the same gauge that is used for testing the valves.

A special connection should be provided to fit the valve openings leading to the indice of the diaphragms. This connection attached to flexible tubing, is held in place by hand and is made gas tight by a washer of sponge rubber. If the diaphragms be not tight and cannot be made so by re-oiling, they should be replaced with new ones and tested for tightness as above. The age limit for diaphragms that can be re-oiled and continued in service, during the next periodical test date, depends upon the quality of the gas, the location of the meter, and the amount of gas the meter has passed at varying speeds. From observation, it is recommended that diaphragms be left in meters not more than fourteen years.

Gas Pipe Sizes

SIZE OF PIPE INS.	NUMBER OF 3/8 INCH OUTLETS 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
3/8	20																				
1/2	30	27	12																		
3/4				50	33	24	18	13													
1							70	50	44	35	30	25	21	18	16	14	12				
1¼										100	90	75	60	53	45	41	36	32	29	27	24
1½													150	130	115	100	90	80	73	65	58
2																					
2½																					
3																					
4																					

SIZE OF PIPE INS.	22	23	24	25	30	35	40	45	50	65	75	100	125	150	175	200	250	300	350	400	500
3/8																					
1/2																					
3/4																					
1																					
1¼	22	20	18	17	12																
1½	53	49	45	42	30	22	17	13													
2		200	190	175	120	90	70	55	45	27	20										
2½					300	270	210	165	135	80	60	33	22	15							
3								400	330	200	150	80	50	35	28	21	14				
4											600	360	230	160	120	90	59	39	29	22	14

CHAPTER 136

Gas Pipe Fitting

Size of Pipe.—In the installation of gas piping no pipe should be smaller than ⅜ in. on concealed work and no pipe smaller than ½ in. should be used for concealed horizontal lines. The size of pipe will depend on

1. Length; and
2. Number of outlets.

The table of pipe sizes on this page gives the number of ⅜ in. outlets for different sizes of pipe and maximum length of pipe line.

Note the table is based on ⅜ in. outlets.

The method of arriving at the size of pipe needed for various requirements will now be given.

The size of pipe necessary to install considering all conditions depends on:

1. Length of pipe.
2. Maximum gas consumption.
3. Allowable pressure drop.
4. Specific gravity of the gas.

The specific gravity of most gases varies between .45 and .65 and as the capacity of pipe is only affected by this factor inversely as the square root, it is sufficiently accurate to use an assumed gravity of .6 for all calculations.

TABLE 1

Showing Capacity of Pipe of Different Diameters and Lengths in Cu. Ft. per Hour with Pressure Drop of 0.2 In. and Specific Gravity 0.60

To Be Used for Figuring Laterals and Service Pipes.

Length of pipe, ft.	Diameter of pipe, in.								
	¾	1	1¼	1½	2	3	4	6	8
15	168	350	620	960	2000	5400	11200	31000	63000
30	120	245	430	680	1400	3800	7900	21500	44000
45	98	200	355	530	1150	3200	6500	18000	36500
60	84	175	310	480	1000	2700	5600	15500	31500
75	76	155	275	430	890	2450	5000	13700	28000
90	70	145	250	395	810	2260	4550	12500	26000
105	64	132	232	370	750	2100	4200	11500	24000
120	60	125	215	340	700	1950	4000	11000	22000
150	54	110	195	310	630	1750	3550	9800	20000
180	49	100	175	280	570	1600	3200	8900	18000
210	44	94	165	260	530	1450	3000	8200	16500
240	43	88	155	240	500	1350	2800	7700	16000
270	40	83	145	230	470	1300	2650	7100	15000
300	38	79	138	215	440	1250	2500	6900	14000
450	31	64	112	176	360	1000	2050	5600	11500
600	27	56	97	152	315	860	1750	4900	10000

Table 1 and 2 are both based on this value, but if it be desired to use the exact gravity for a particular condition, the values in the two tables can be corrected by multiplying by

$$\sqrt{\frac{.6}{\text{Sp. gr.}}}$$

The unit for measuring the pressure of manufactured gas is *inches of water*, and it will be noted in Table 1 that the gas capacities for the various pipe sizes are given for a .2 in. pressure drop. In Table 2 the drop allowed is .5 in. These two tables are given in order to compensate for the different conditions encountered in calculating lateral feed pipes as against vertical or riser pipes. Table 1 is for laterals and Table 2 for risers.

There are two reasons which permit a greater pressure drop to be allowed on risers.

First, the drop in pressure due to the ordinary friction loss is reduced by the gas column which is lighter than air and therefore causes an increase in pressure with altitude. For a gas with a specific gravity of .6 this increase is approximately 1 in. (of water) per 170 ft. of elevation.

TABLE 2

Showing Capacity of Pipe of Different Diameters and Lengths in Cu. Ft. per Hour with Pressure Drop of 0.5 In. and Specific Gravity 0.60

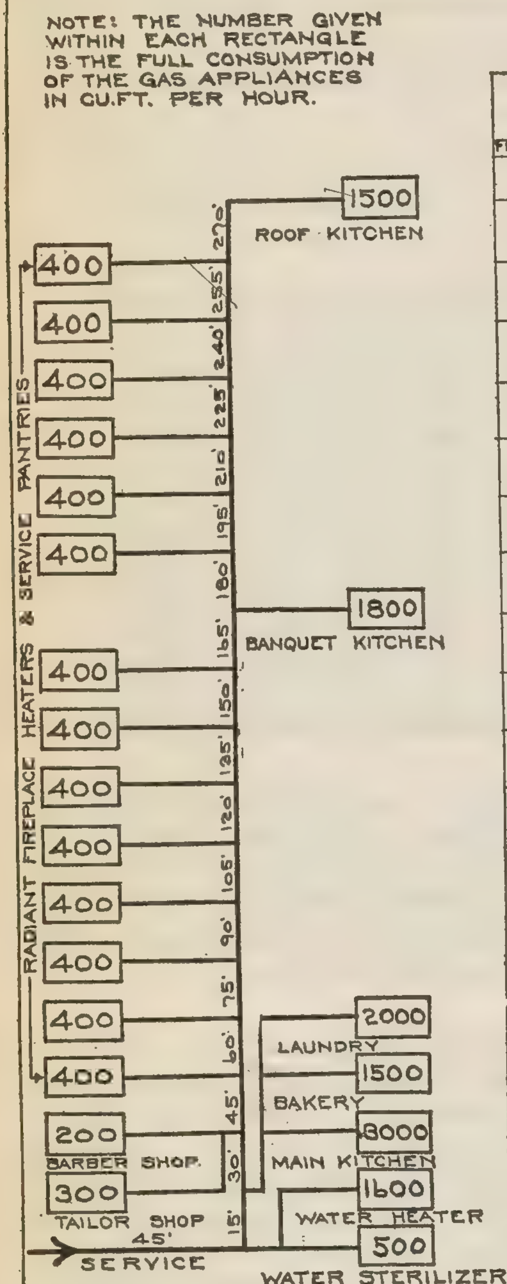
To Be Used for Figuring Verticals and Risers.

Length of pipe, ft.	Diameter of pipe, in									
	¾	1	1¼	1½	2	3	4	5	6	8
15	270	560	980	1540	3200	8600	17800	31000	49000	100000
30	190	390	680	1080	2200	6100	12500	22000	34500	71000
45	155	320	560	890	1800	5000	10300	18000	28000	58000
60	135	280	490	770	1600	4300	8900	15500	24500	50000
75	120	250	430	680	1400	3800	8000	14000	22000	45000
90	110	230	400	620	1300	3500	7300	12500	20000	41000
105	102	210	370	580	1200	3300	6800	11800	18500	38000
120	96	200	345	545	1100	3100	6300	11000	17400	36000
150	87	180	310	490	1000	2700	5600	9800	15500	32000
180	79	160	280	445	900	2500	5100	8900	14000	29000
210	73	150	260	410	840	2300	4800	8300	13000	27000
240	68	140	245	385	790	2150	4400	7700	12300	25000
270	65	130	230	365	740	2050	4200	7300	11500	23500
300	61	125	220	345	710	1950	4000	7000	11000	22500
450	50	100	180	280	570	1600	3200	5600	8900	18000
600	43	88	150	240	490	1350	2800	4800	7600	15500

Second, the possibility of all gas appliances being in use at one time is very remote, particularly on the different floors. A greater diversity can be expected when a variety of uses is included than when only one use is considered and a more liberal factor can therefore usually be allowed for risers than for laterals. In order to show how Tables 1 and 2 can be used in designing a pipe, an example applied to each will be given.

Example.—A hotel is to be erected with gas requirements as called for in fig. 9,004. The number marked in each rectangle is the maximum gas demand for each requirement and is expressed in cu. ft. of gas per hour. The hotel is 16 stories high with a basement and sub basement. On the roof there is a restaurant with a kitchen having a maximum demand of 1,500 cu. ft. per hour. The tenth floor has a banquet kitchen, the first floor a barber and tailor shop, the basement contains the main kitchen, bakery and laundry and the sub basement a water heater and drinking water sterilizer. On each of the room floors there are service pantries and radiant fireplace heaters in the sitting rooms of the suites.

To figure the size of the risers, start at the top floor. Here is 1,500 cu. ft. which must travel through 270 ft. of pipe; refer to table 2 and find that



FLOOR	MAXIMUM GAS DEMAND IN CU. FT. PER HOUR AT FLOOR	LINEAR FEET OF PIPE FROM STREET SERVICE TO FLOOR	SIZE OF GAS RISER IN INCHES CALCULATED FROM TABLE 2
R	1500	270	3
16	1900	255	3
15	2300	240	4
14	2700	225	4
13	3100	210	4
12	3500	195	4
11	3900	180	4
10	5700	165	5
9	6100	150	5
8	6500	135	5
7	6900	120	5
6	7300	105	5
5	7700	90	5
4	8100	75	5
3	8500	60	5
2	8900	45	5
1	9400	30	5
B.	15900	15	5
S.B.	18000	[TABLE 1]	6

FIG. 9,004.—Diagram showing the gas demand for the various floors of a typical hotel.

it will be necessary to provide 3 in. pipe. On the sixteenth floor there is 1500+400=1900 cu. ft. which must travel through 255 ft. of pipe; this also calls for 3 in. pipe, etc. (See computation table in fig. 9,004 for complete layout). The service will have to supply 18,000 cu. ft. per hour, and as it is 45 ft. long, find from table 1 (laterals) that this calls for 6 in. pipe.

As an example for calculating pipe sizes for laterals, the requirements for the basement containing the main kitchen, bakery and laundry will be figured. Fig. 9,005 shows a plan of this floor and it will be noted that

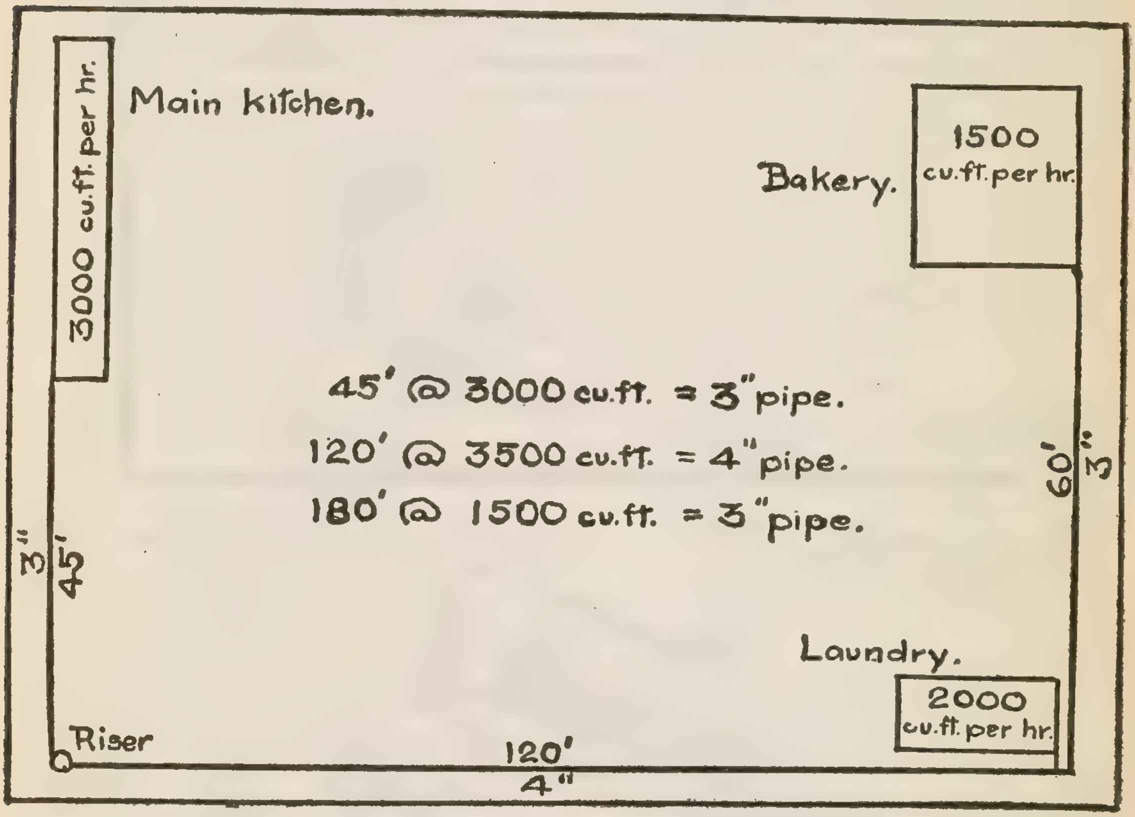


FIG. 9,005.—Layout for basement of hotel.

the kitchen which has a demand of 3,000 cu. ft. per hour is located 45 ft. from the riser. Refer to table 1 and find that it will require 3 in. pipe for this section.

The laundry and bakery are so located that it will be necessary to have a common lateral for both as far to the laundry. The common run for both is 120 ft. long and will have to provide for 2,000+1,500=3,500 cu. ft. (4 in. pipe). From the laundry to the bakery is 60 ft. additional, making a total of 120 ft.+60 ft.=180 ft. with a demand of 1,500 cu. ft. per hour. Table 1 shows that 180 ft. of 3 in. will pass 1,600 ft. which is therefore ample.

Installation of Piping.—Standard weight wrought pipe is used with Briggs standard threads. The following table gives the approximate number of threads and length of threaded portions to be cut for each size pipe.

Amount of Threading for Pipes

Size of pipe, inches	Approximate length of threaded portion in inches	Approximate number of threads to be cut
3/8	9/16	10
1/2	3/4	10
3/4	3/4	10
1	7/8	10
1 1/4	1	11
1 1/2	1	11
2	1	11
2 1/2	1 1/2	12
3	1 1/2	12
4	1 5/8	13

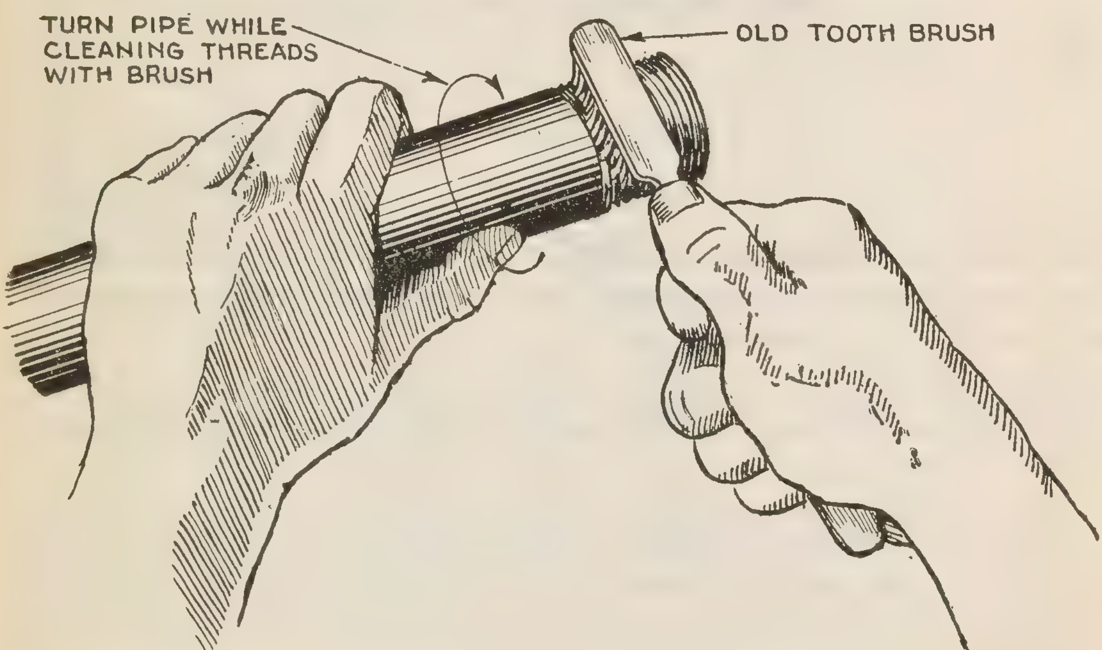


Fig. 9,006.—Method of cleaning *male* threads with old tooth brush.

The pipe should first be cut off square and proper care taken to cut perfect thread. In making up the joints, the threads of both male and female ends must be perfectly clean. The author's method of cleaning pipe threads with an old tooth brush is shown in figs. 9,006 and 9,007.

The bristles of the brush should be stiff. Too much care cannot be given to this part of the work as a perfect joint cannot be made with dirty threads.

An approved jointing compound should be used and it should be put on the male thread sparingly yet the entire threaded portion should be covered. Sealing wax or any material or compound known as "gas fitters cement" should not be used in making up the joints. All branches should be taken from the top or side of a horizontal and not from the bottom. When ceiling

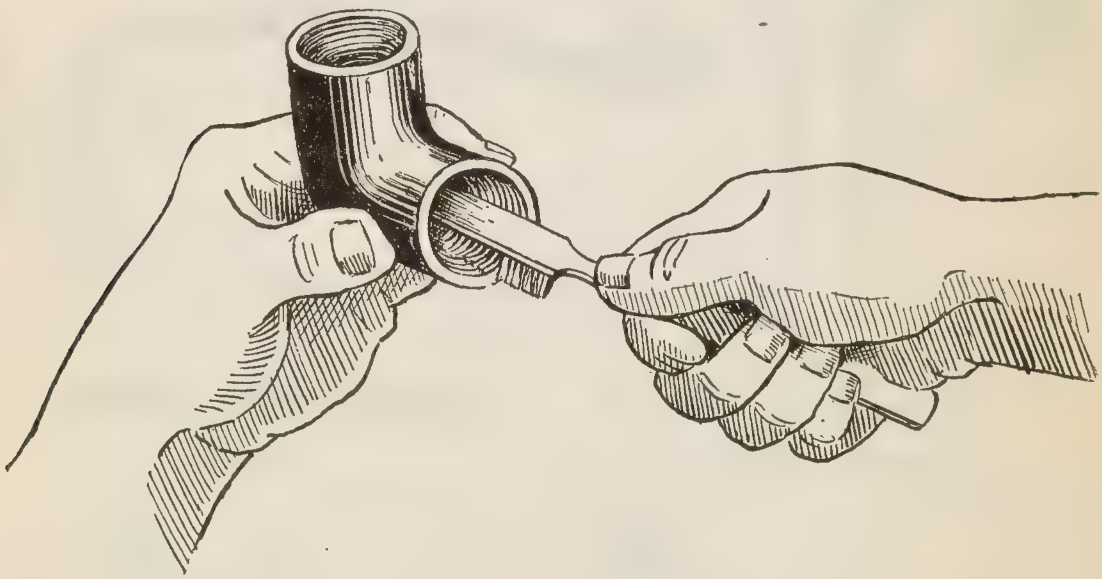


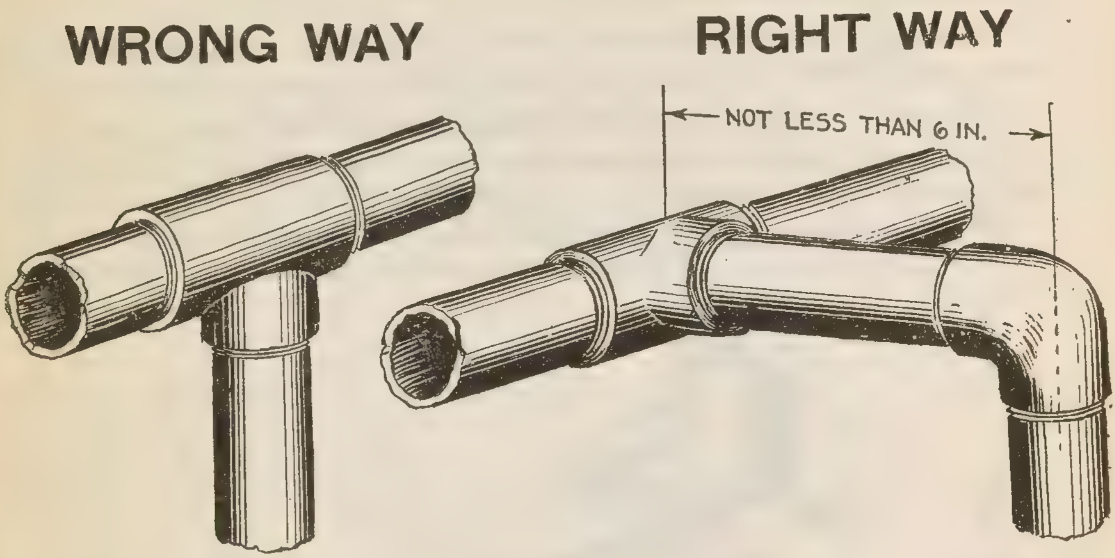
FIG. 9,007.—Method of cleaning *female* threads with old tooth brush.

outlets are taken from horizontal piping, the branch should be taken from the side of the piping and carried in a horizontal direction, preferably not less than 6 ins. In bending pipe, care should be taken that it does not kink, and not bent to radii less than in the following table.

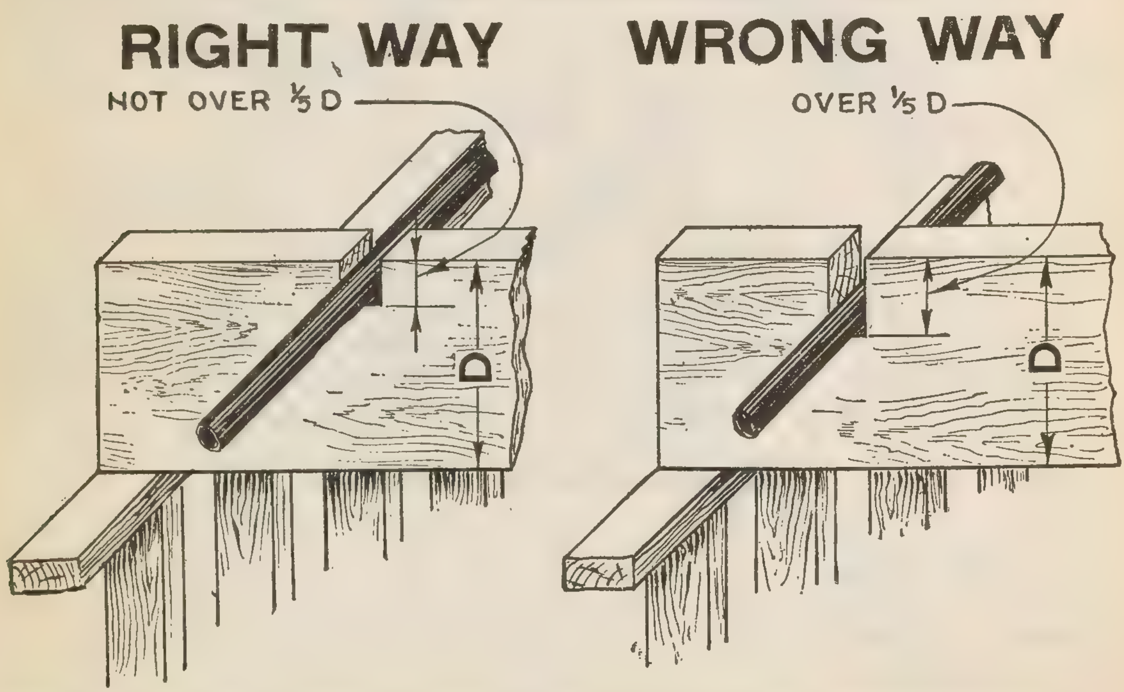
Minimum Radii for Bends

Size of Pipe (inches).....	⅜	½	¾	1	1¼	1½	2
Minimum Radius of bends (inches)........	3	4	6	8	12	15	18

In the installation of pipe care should be taken that it is properly supported and not subjected to any unnecessary strain.



FIGS. 9,008 and 9,009.—Wrong and right way to connect a drop branch to a horizontal pipe

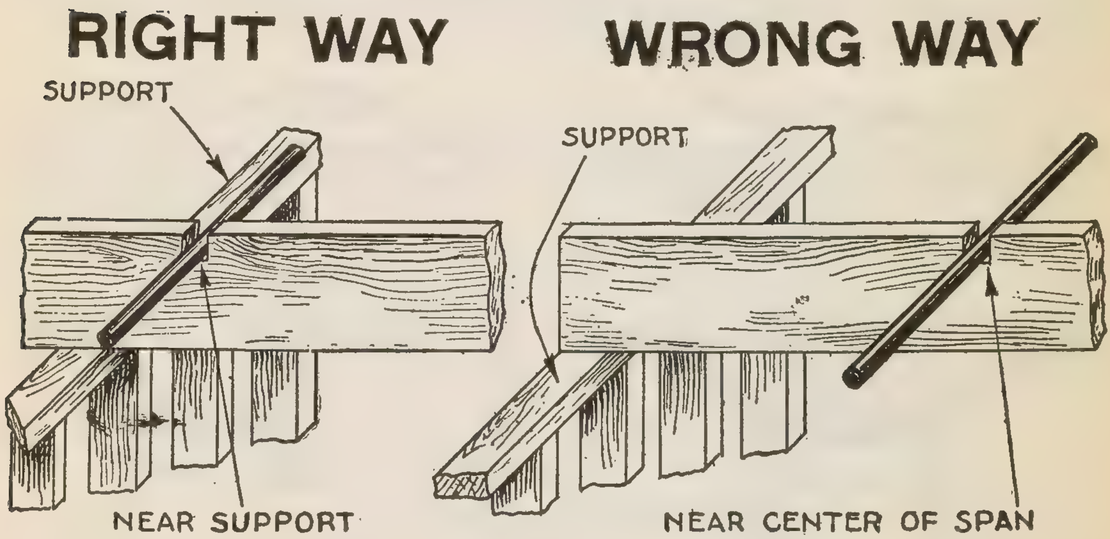


FIGS. 9,010 and 9,011.—Right and wrong way to cut joists in installing horizontal piping.

The following table gives the maximum spacing of supports for various size pipes.

Spacing of Supports

3/8 in. or 1/2 in. pipe	6 ft.
3/4 in. or 1 in. pipe	8 ft.
1 1/4 in. or larger (horizontal)	10 ft.
1 1/4 in. or larger (vertical)	every floor level.



FIGS. 9,012 and 9,013.—Right and wrong location of pipes run across joists.

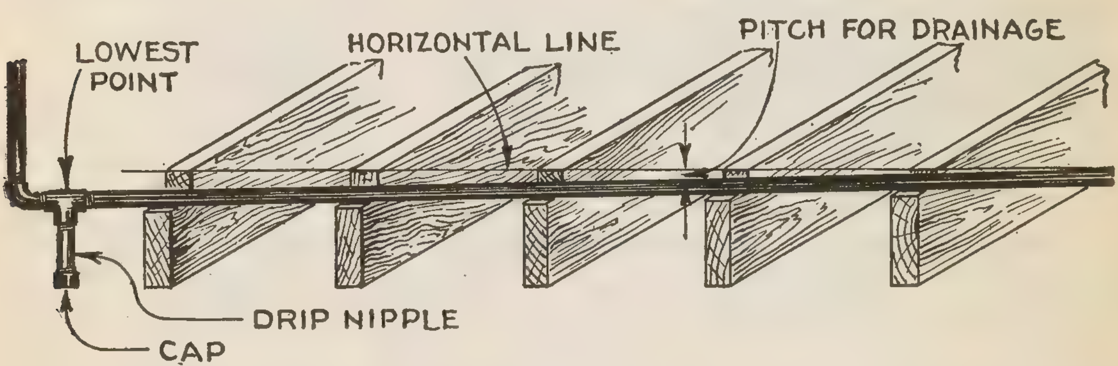
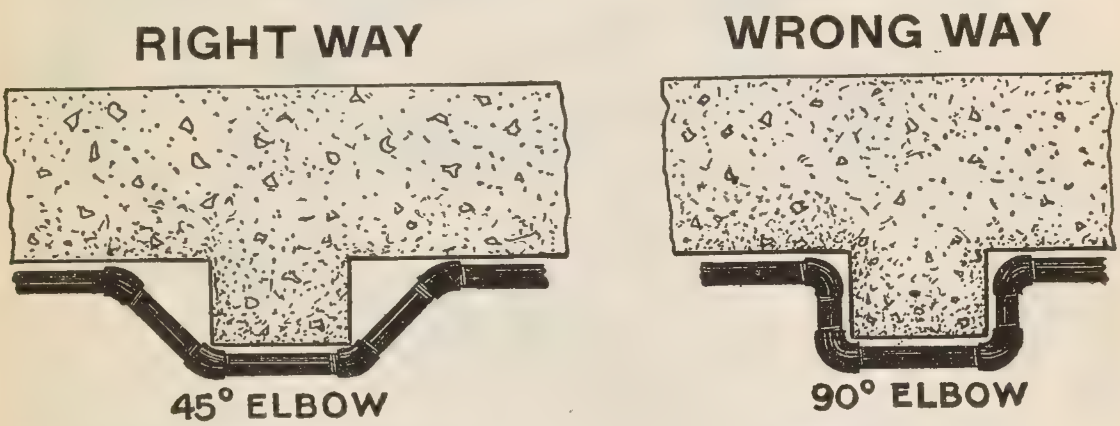


FIG. 9,014.—Horizontal line with pitch for drainage of any condensed liquid, and drip nipple at lowest point to collect liquid.

When the length of pipe is shorter than that given in the above table, it should be adequately supported. Wherever there is a change of direction of 45° or more, or a branched fitting is used, support should be provided on at least one side of the bend or fitting, preferably within 6 in. of this joint, unless other supports render this unnecessary.

Pipe straps or iron hooks should not be used for fastening pipe of a size over 2 ins. Beyond this size, when the pipe is horizontal and is to be fastened to the floor joists or beams, pipe hangers should be used; when the pipe is horizontal and is to be fastened to the wall, hook plates should be used.

When pipes run crosswise to beams, do not cut the beams to a depth of more than one-fifth of the depth of the timber. This cutting should be as near the support of the beam as possible and in no case should it be further from a support than one-sixth of the span.



Figs. 9,015 and 9,016.—***Right*** and ***wrong*** way of making pipe offsets.

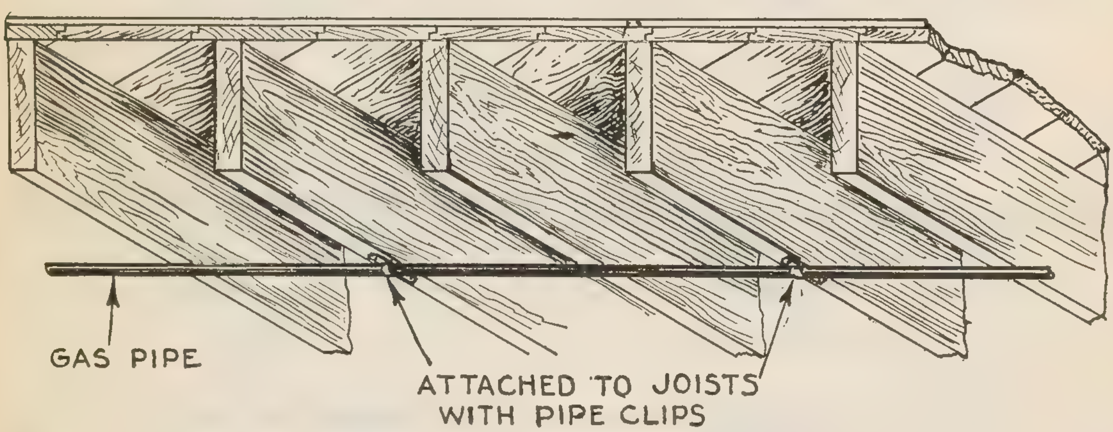


Fig. 9,017.—Right way of running pipe in cellar by hanging from joists instead of supporting on wall.

When possible run pipes parallel with the beams to avoid cutting and resulting weakening of the beams. Horizontal lines should have some pitch to provide for drainage of any condensed liquid especially where pipes are exposed to cold. At the lowest point on a trapped section where such

cannot be avoided, a T with a proper length nipple (looking down) and a cap should be provided to facilitate the removal of the liquid.

The size drip to use should be in proportion to the amount of exposed section which drains into it. Fig. 9,014 shows T and drip nipple.

Where an offset is necessary as in the case of an increase in the thickness of a wall, the offset should be made with 45° elbows as shown in fig. 9,015 in preference to 90° elbows as in fig. 9,016 to reduce friction to flow and reduce the likelihood of stoppage. Where piping is run in a cellar it should

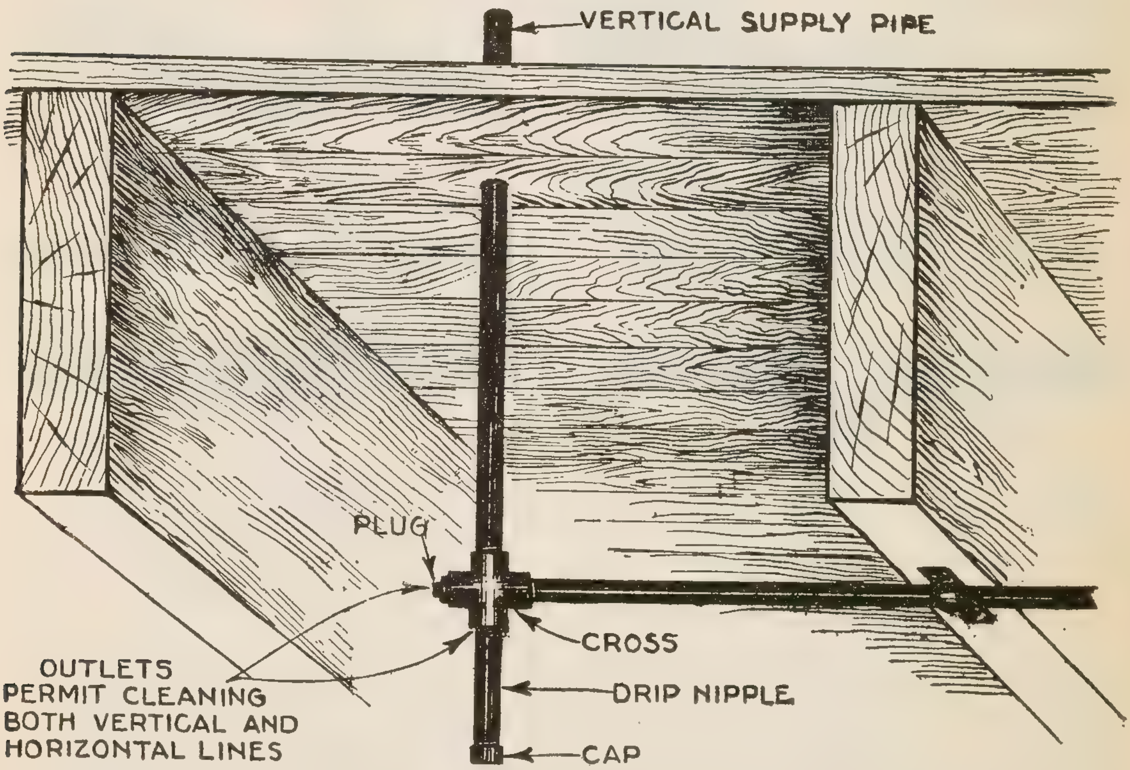
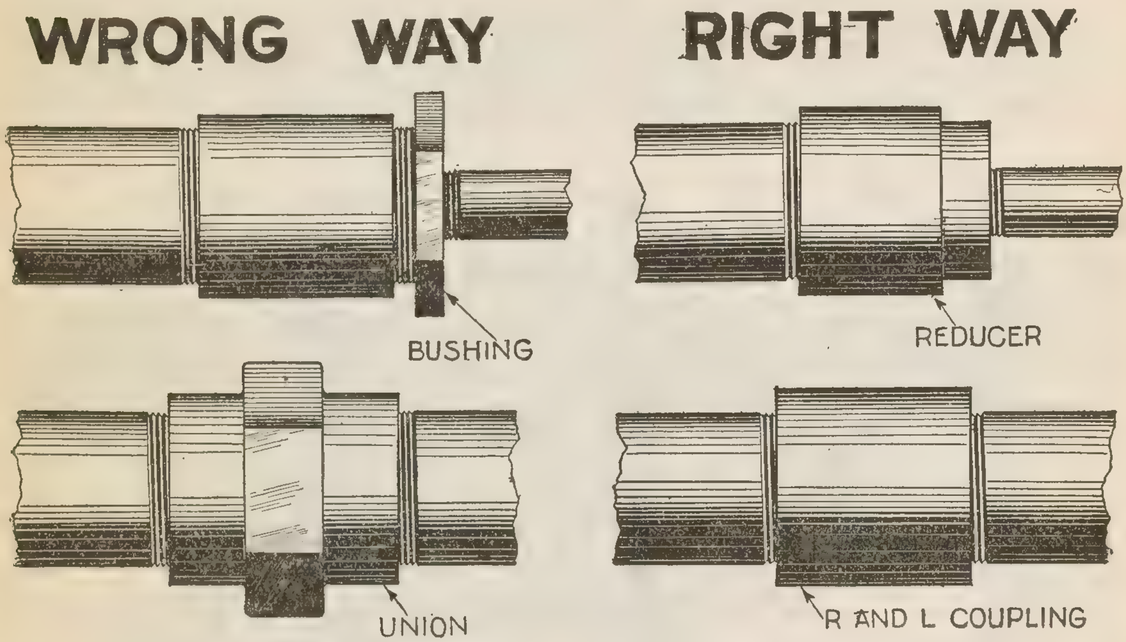


Fig. 9,018.—Proper connection of inlet horizontal line with vertical supply pipe. By using a cross as shown both pipes may be cleaned. On the lower opening a drip nipple provides a receptical for the drainage of any condensed liquid that be present.

be hung from the ceiling or joists, as in fig. 9,017, and not supported on the walls.

Prohibited Fittings.—In reducing the size of pipes a bushing should not be used; the connection should be made with a reducer. Unions should not be used, as they are liable to leak

if not made up properly. Use instead a right and left coupling. On concealed piping, swing joints made by use of combination of fittings should not be used.



FIGS. 9,019 to 9,022.—Prohibited fittings and methods of avoiding them.

CHAPTER 137

Illumination

Illumination.—The term "illumination" may be defined as *the density of light flux projected on a surface*, and by extension, it denotes *the* **art** *of using artificial sources of light*, that is to say the problem of illumination involves *the* **selection** *and* **arrangement** *of these artificial sources of light* so that the objects to be lighted will show up to the best advantage and with the minimum amount of artificial light.

The subject is naturally divided into several sections, as

1. Nature of light;
2. Nomenclature;
3. Measurement of light;
4. Selection and placement of light units.

Nature of Light.—By definition: *Light is a* **rapid vibratory motion** *which is transmitted in the form of waves on the ether;* in other words, *light is a* **sensation** *received through the organ of sight and is caused by waves which are transmitted on the ether.*

In nearly all cases, those bodies which give out light are also very hot. The light waves and the heat waves are the same in character but different in length. The light waves are shorter. The heat waves are not visible because the eye is so constructed that only waves of a certain length will produce the sensation which is called vision.

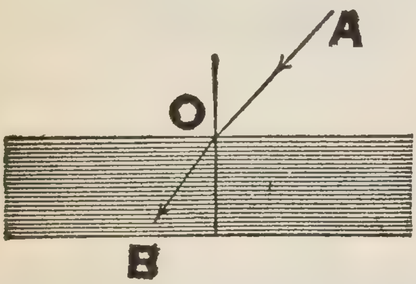
Ques. How is light propagated?

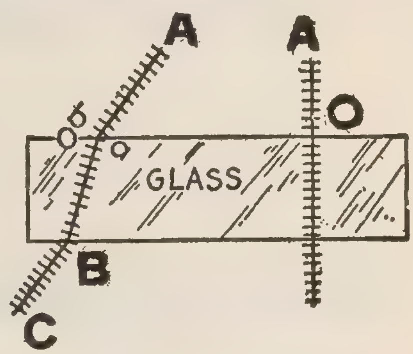
Ans. Light waves move out in every direction from a luminous point.

The portion of the ether which is affected by the waves is spherical in shape provided there be no obstacles in the way.

Technical Terms.—The following definitions of terms used in illumination should be carefully noted.

Ray.—The direction in which a light wave is advancing.



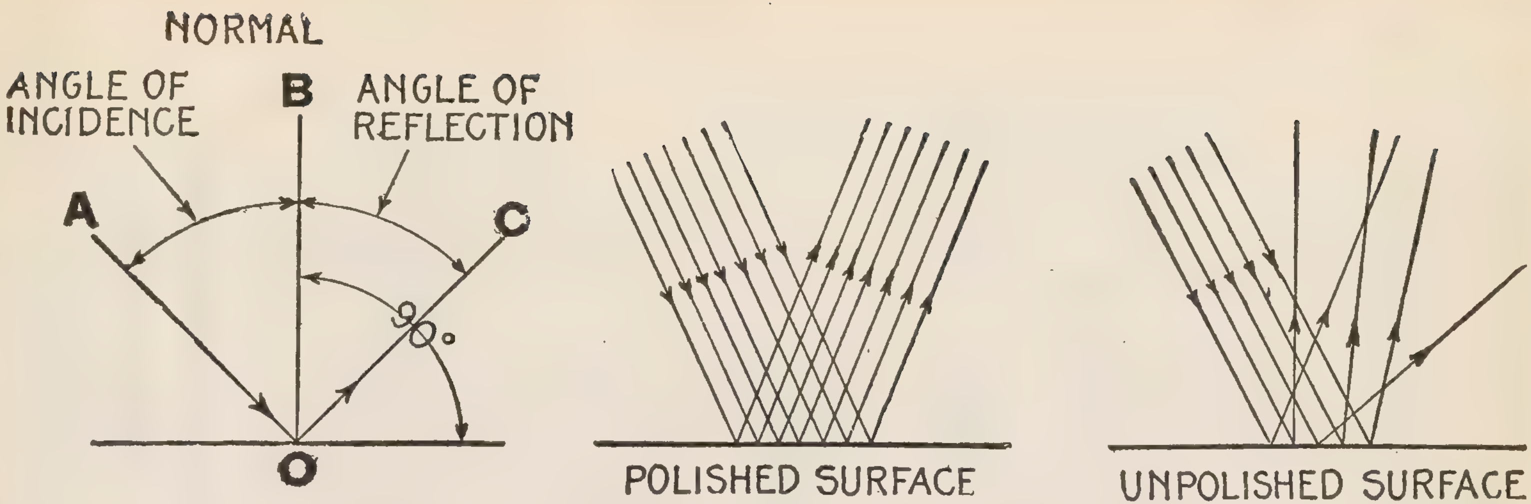


FIGS. 9,023 and 9,024.—Diagram illustrating the refraction of light. *Refraction is the bending which occurs when rays of light pass from one medium into another.* Ray A O, passes straight through the air to the surface of water, but on entering the water it is bent, so that it passes along O B. The ray is refracted at O. Some media will refract light much more than others. In general it may be said that the more dense a medium is, the more the rays will be refracted when they pass into it. ***Cause of Refraction.*** Light moves with less speed through a dense medium than through a rarer one. The speed is less in air than in the ether space beyond the atmosphere. It is less in water or glass than in air. In fig. 9,024, let A O, represent a ray of light, that is, the direction in which the waves of light advance. Let the short lines drawn across the ray represent the waves. The wave *ab* is just entering the glass. The end *a* enters first and its speed is checked, while the end *b* continues its speed until it also reaches the glass. Thus the wave is caused to swing about, just as a line of soldiers is swung around when the men at one end of the line do not walk as rapidly as those at the other. The wave will then advance through the glass in a straight line but in a direction O B. At B, the wave will again pass into the air. The part which was first to enter at O, is the first to emerge at B. The direction of the wave is again changed and it passes on along B C. In case the ray be perpendicular to the surface of the glass, the speed is checked but there is no refraction, for as shown both ends of the lines on A′ O′, enter the glass at the same time.

Beam.—Several parallel rays.

Pencil.—Several rays converging to a point.

Medium.—Any space or substance which light can traverse, such as a vacuum, air, water, glass, etc.



FIGS. 9,025 to 9,027.—Diagrams illustrating ***reflection*** and ***diffusion*** of light. When light waves meet an obstacle in their path, they are reflected according to the following law: *The angle of reflection is equal to the angle of incidence.* That is to say, in fig. 9,025 if a ray of light strike a surface at an angle AOB, it will be reflected from the surface at an equal angle BOC, the common side OB, being a normal or perpendicular to the surface When light is reflected from a smooth surface, such as plane polished metal or glass, the reflected rays continue in the same relation to each as before reflection, as in fig. 9,026. If the surface be not polished, the rays are reflected from a countless number of small surfaces which are not in the same plane. Each ray is reflected according to the law given above, but since the small surfaces from which they are reflected are at every possible angle to each other, the reflected rays will be in every possible direction, as in fig. 9,027. Such light is said to be *diffused*. Most objects are seen by diffused light. A perfectly plane polished reflector can not be seen at all.

Absorption.—The absorption of light rays by a body through which they are passing, as illustrated by the effect upon the intensity of an electric light by the globe of the lamp.

Diffraction.—A modification which light undergoes when passing the edge of a body in virtue of which the luminous rays appear to become bent and to penetrate into the shadow.

Luminous Bodies.—Those which give out light to other bodies.

Non-luminous Bodies.—Those which are not the origin of light waves but may become visible when

the waves from luminous bodies fall upon them and are reflected thence to the eye.

Fluorescence.—The property possessed by some transparent bodies, of giving off, when illumined, light of a color differing from their own and from that of the incident light.

The light given off is usually of greater wave length than the incident light, and the violet and ultra-violet rays are the best exciters of it.

Phosphorescence.—A manifestation of luminescence, in which light, previously absorbed, is emitted by a body for a considerable time after the original source of light has ceased to act upon it.

Phosphorescence is mostly due to slow oxidation attended with light as in phosphorus, or by the molecular vibrations causing the emission of light after the source of light has been removed.

Opaque.—Not having the power of transmitting light; impervious to light rays.

Transparent.—The quality of a body through which light may freely pass and objects may be distinctly seen.

Translucent.—The quality of a medium which has the power of transmitting light, without permitting clear vision through it, as distinguished from transparent.

Shadow.—A deficiency of light within an illuminated region, caused by the interception of the light by an opaque body.

Candle Power.—A unit for the measurement of the intensity of all lights.

Measurement of Light.—*Brightness* is the name of a sensation, as is loudness in the case of sound. The degree of brightness depends upon the intensity of the light, but the eye is not capable of measuring the intensity with any degree of accuracy. The eye is, however, able to detect very slight differences in the illumination of two surfaces which are side by side.

Ques. On what does the intensity of light depend?

Ans. On the amount of energy in the light waves.

The amount of light which falls upon a given unit of area is called the *intensity of illumination*.

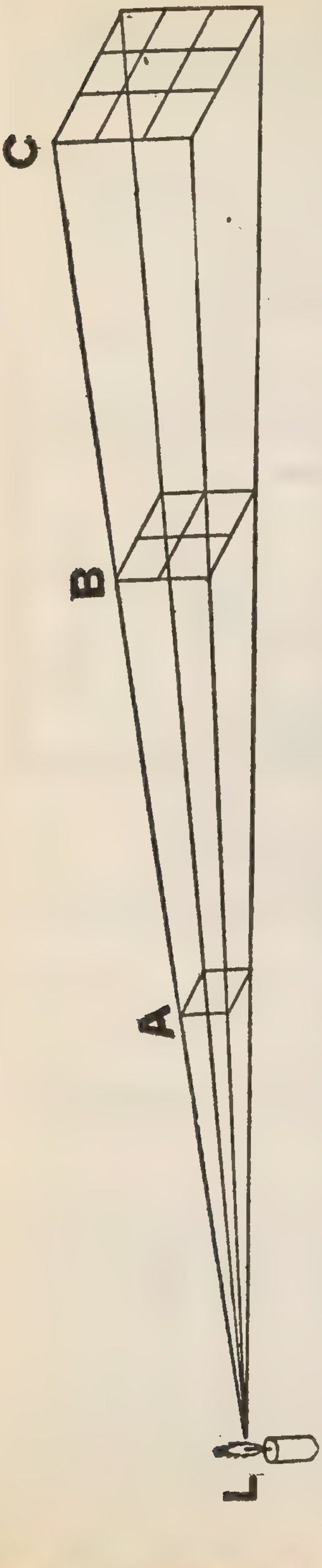


FIG. 9,028.—THE LAW OF INVERSE SQUARES: ***The intensity of the illumination due to a given point source varies inversely as the square of the distance from the source.*** Let L, represent a point source of light and let A, be a screen 1 ft. square placed at a distance of 5 ft. from L. Since light travels in straight lines the shadow which the screen casts on a wall B, 10 ft. from L, will have an area of 4 sq. ft. If now the screen A, be removed the light which will then fall upon the 4 sq. ft. occupied by the shadow must be exactly the same as that which before fell upon the screen 1 ft. square. Since this light is now spread over 4 sq. ft. each square foot can receive but one-fourth as much light as fell upon the screen A. If the wall were at C, 15 ft. from L, instead of 10 ft., precisely the same reasoning would show that each sq. ft. would receive but one-ninth of the light which fell upon A.

Ques. What standard is employed for measuring light?

Ans. The candle power.

Ques. What is one candle power?

Ans. The amount of light emitted by a sperm candle seven-eighths inch in diameter and burning 120 grains (7.776 grams) per hour.

International Candle.—This is the present unit and is derived from the mean intensity of a group of incandescent electric lamps, maintained by the U. S. Bureau of Standards, in co-operation with similar custodians in France and Great Britain.

Pentane Standard.—A standard of illumination employing a lamp with a specially constructed burner consuming a mixture of 7 parts of pentane gas and 20 parts of air at the rate of a half cubic foot per hour.

Hefner Standard. — The light unit adopted in the United States and Germany. It is the light given by an amyl-acetate flame adjusted until its tip is 40 mm. above the top of the wick tube. Its standard intensity is .9 international candle.

Carcel Standard.—The Carcel lamp used in France. It has a central draught rug burner filled with a wick of the light house type burning 42 grams of pure Colza oil or rape seed oil per hour. Its standard intensity is 9.61 international candles.

Comparison of Standards.—The relative intensity of the several standards are given in the following table:

Comparison of Candle Power Standards

	International candle	Hefner	10 C. P. pentane	Carcel	Bougie decimale	English candle	German candle
International candle.......	1 00	1.11	.1	.104	1.	.96	.95
Hefner.........	.9	1.	.09	.0936	.9	.864	.855
10 c. p. pentane.	10.	11.11	1.	1.04	10.	9.6	9.5
Carcel....	9.61	10.66	.96	1.	9.6	9.24	9.19
Bougie decimale	1.	1.11	.1	.104	1.	.96	.95
English candle..	1.04	1.154	.104	.1	1.04	1.	.98
German candle.	1.055	1.17	.105	.109	1.055	1.02	1.

Ques. What is a lumen?

Ans. The standard of luminous flux, being the light sent out from a unit source through a unit solid angle.

Ques. What is a lux?

Ans. The unit of illumination proposed by the Geneva Congress in 1896.

A lux is the sectional intensity of a one candle power beam at a distance of one meter from the source of light, that is, it is a *meter candle*, since 1 meter = 3.1 foot, one meter candle = $3 \div (3.1)^2$ candle foot.

The lamp of the Hefner standard consists essentially of a cylindrical base for holding the amyl-acetate which is drawn up through a German silver tube by means of a specially prepared wick. The objections to the Hefner standard are its low intensity, its reddish color, its flabby flame and its sensitiveness to variation in flame height. The element of uncertainty associated with it at best is not less than 2 per cent.

Ques. What is a candle foot?

Ans. The illumination produced by a light of one candle-power at a distance of one foot.

An intensity of one candle foot is produced by the light from a standard candle at 1 foot from it, in the same horizontal plane as the flame, at 2 feet distance the intensity is ¼ candle foot, at 10 feet $^1/_{100}$ candle foot. A 32 candle electric lamp at 6 feet produces an intensity of $^{32}/_{36}$ candle feet, etc.

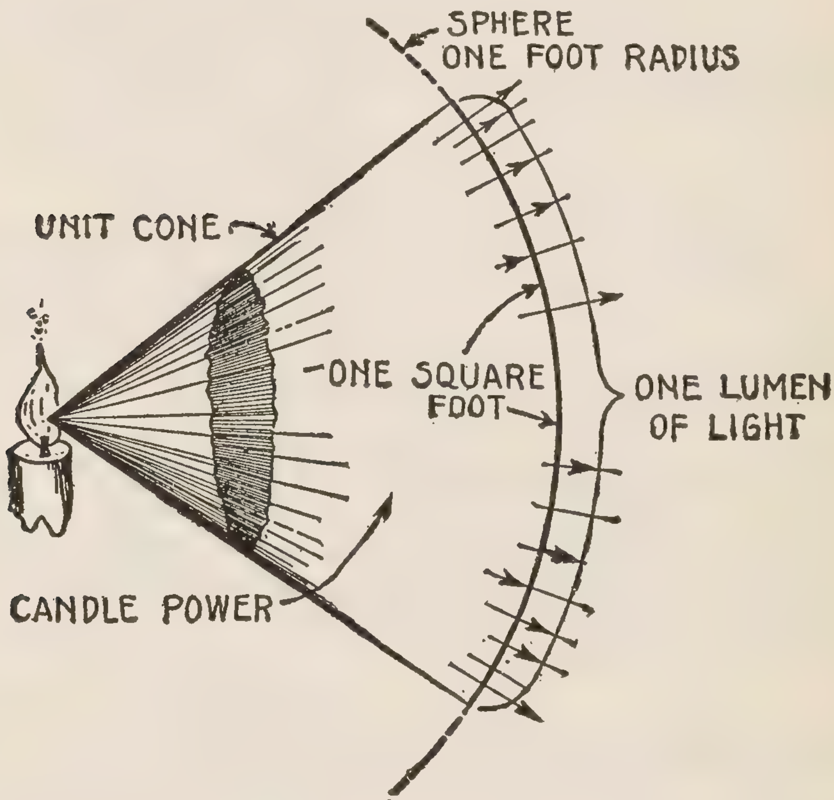


Fig. 9,029.—A unit cone. ***Imagine*** a standard candle as shown in the figure and a sphere of one foot radius with its center at the candle. One square foot of the surface of this sphere is contained inside of a unit cone, and such cone contains one ***lumen*** of light flux. Therefore, one lumen of light flux passes through each square foot of the surface of the sphere; that is, the light which radiates from the given lamp has a sectional intensity of one lumen per square foot *at a distance of one foot from the lamp*. This sectional intensity is sometimes called the ***foot candle***. That is to say, the foot candle is the sectional intensity of a one candle power beam at a distance of one foot from the lamp. The ***meter candle*** is the sectional intensity of a one candle power beam at a distance of one meter from the lamp. The meter candle is one lumen per square meter and it is sometimes called the *lux*.

A candle foot is also defined as *the illumination produced by one candle power falling perpendicularly on a surface at a distance of 1 foot.*

Ques. Define mean conical candle power.

Ans. This unit, sometimes called the mean zonal candle power, is the mean of the candle power in all directions making a given angle θ with the equatorial plane of a lamp; it is the mean conical candle power at the angle θ.

All these directions lie on a cone the vertex of which is the center of the lamp and the axis of which coincides with that of the lamp. The semi-vertical angle is $90°—\theta$. If the mean conical candle power at certain angles be measured, the average of the results is the mean spherical candle power.

Ques. Define mean spherical candle power.

Ans. If there be drawn from a source equally in all directions lines whose lengths are proportional to the candle power in these directions, then the mean value of the lengths of all these lines is the mean spherical candle power.

Ques. Define mean hemispherical candle power.

Ans. If there be drawn from a source equally in all directions either below or above the equatorial plane, lines whose lengths are proportional to the candle power in these directions, then the mean value of the lengths either above or below is the mean hemispherical *c. p.* of the upper or lower hemisphere respectively.

Ques. Define mean horizontal candle power.

Ans. If, from a source of light there be drawn lines equally in all directions in a plane, and their lengths be made proportional to the candle power in these directions then the sum of all these lengths, divided by their number, gives the mean candle power in that plane.

When the axis of the lamp is vertical, the mean candle power in the horizontal plane is called the mean horizontal candle power.

Ques. What is photometry?

Ans. Photometry is the process of measuring the intensity of light.

The instrument by which the candle power is determined is called a photometer.

Ques. What is an integrating photometer?

Ans. A photometer which gives directly, by one reading, the average light emitted around a meridian line.

If the source of light be turned about a vertical axis through definite angles, and candle power readings be taken in each meridian, the mean spherical candle power can be obtained by taking the average of these.

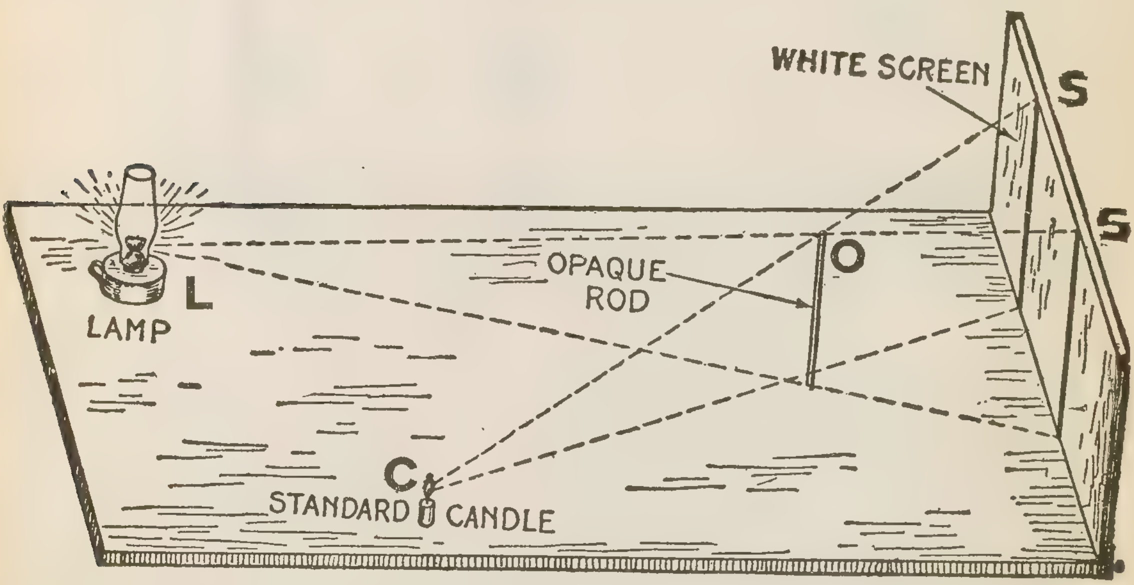


Fig. 9,030.—Principle of Rumford's photometer. *A screen is equally illuminated by each of two sources of light whenever the two shadows cast by the same object are equally illuminated*, that is, have the same depth of shadow. In the diagram L and C, are the two sources of light, L, being a lamp, and C, a standard candle. An opaque rod is placed near the white screen. Two shadows will be formed on the screen side by side. The light from the candle falls upon the shadow S, and the light from the lamp falls upon the shadow S. The distances of L and C, from the screen may be adjusted so that the two shadows will look exactly alike. Since the intensity of any light varies inversely as the square of the distance increases, then the comparative power of two sources of light must vary directly as the squares of their distances from the screen which they illuminate equally. Thus if C, in the figure be 50 cm., L, 290 cm. from the screen, and the shadows be alike, the distances are as 1 to 4. The illuminating powers are then as 1 to 16. If C, be 1 *c.p.*, then L, is 16 *c.p.*

Requirements of Good Illumination.—The term good illumination implies that the light units have been so selected and distributed that objects may be clearly seen with a minimum of fatigue.

To obtain this result certain conditions must be fulfilled, as follows:

1. There must be sufficient illumination. Since objects are seen by means of the light which they reflect, more light must be thrown on dark objects than on light ones.

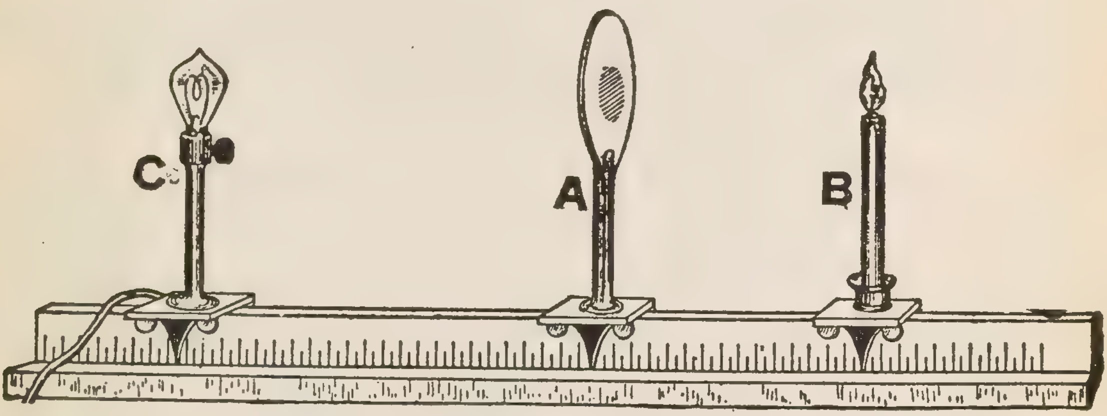


FIG. 9,031.—Bunsen's photometer. ***The principle*** upon which this instrument is based is that *a translucent spot in the center of a white screen will have the same appearance as the rest of the screen when the illumination on the two sides is equal.* A spot in a sheet of white paper may be made translucent by means of a little grease or oil. If this sheet be then held between the eye and a window or other source of light, the grease spot will appear brighter than the surrounding paper. On the other side of the paper the spot appears much darker than the paper. That is to say, *when the paper is viewed from the side of greater illumination, the oiled spot appears dark,* and *when it is viewed from the side of lesser illumination the spot appears light.* Accordingly when the two sides of the paper are equally illumined, the spot ought to be of the same brightness when viewed from either side, which, in fact it is. Hence to find the candle power of any unknown source it is only necessary to set up a candle on one side, and the unknown source on the other, as in the figure, and to move the spot to the position of equal illumination. The candle power of the unknown source will then be $\overline{CA}^2 \div \overline{BA}^2$.

2. There must not be too much illumination. Too strong a light tires the eye, partly due to the muscular effect of contracting the iris, and partly because of the strong light reaching the sensitive retina.

3. Intensely bright lights in the field of vision should be avoided. The iris closes somewhat in order to afford a protection from such lights

and the amount of light received from illuminated objects is thereby so reduced that they cannot be seen clearly.*

TABLE OF INTRINSIC BRILLIANCY OF LIGHT SOURCES

	Candle power per sq. in.
Moore tube	3 — 1.75
Frosted incandescent	2 — 5
Candle	3 — 4
Gas flame	3 — 8
Oil lamp	3 — 8
Cooper Hewitt lamp	17
Welsbach gas mantle	20 — 50
Acetylene	75 — 100
Enclosed A. C. arc	75 — 200
Enclosed D. C. arc	100 — 500
Incandescent lamps	
Carbon 3.5 watts per candle	375
Carbon 3.1 watts per candle	480
Metallized carbon 2.5 watts per candle	625
Tantalum 2.0 watts per candle	750
Mazda 1.25 watts per candle	875
Mazda 1.15 watts per candle	1,000
Nernst 1.5 watts per candle	2,200
Sun on horizon	2,000
Flaming arc	5,000
Open arc lamp	10,000–50,000
Open arc crater	200,000
Sun 30° above horizon	500,000
Sun at zenith	600,000

4. Flickering lights should be avoided.

5. Lamps should be so placed that the light is not regularly reflected into the eye.

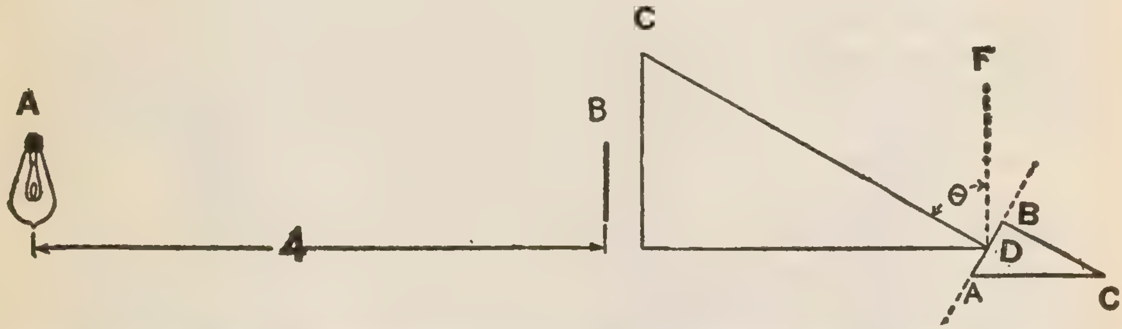
6. Streaks or striations in the illumination are undesirable.

*NOTE.—***A desk lamp*** should be placed to one side rather than directly in front of the person using it, to avoid the glare from the surface of the paper. Smooth reflecting surfaces on the desk, such as plate glass, are undesirable from this standpoint.

7. A satisfactory light must be of a proper quality. It should have a continuous spectrum, that is, one containing every color, in order that the relative color values of objects illuminated may be the same as when seen by daylight.

Calculation of Illumination.—The basis of illumination calculations is the foot candle, already defined, and which is here illustrated in figs. 9,032 and 9,033.

As the computation is more or less involved, these are given in



FIGS. 9,032 and 9,033.—The foot candle. If A, be a lamp giving 16 candle power in a horizontal direction, the illumination at the point B, four feet distant, would be $16 \div 4^2 = 1$ foot candle, since the intensity of light varies inversely as the square of the distance. To get the normal illumination at any given point, the candle power in the proper direction must be divided by the square of the distance to the point illuminated. If the surface illuminated be not at right angles to the direction of the light, the value of the illumination obtained as above must be multiplied by a reduction factor, taking into account the angle at which the rays strike. A beam of light coming in the direction OD, fig. 9,033, falls upon a plane AB, illuminating it with an intensity of 1 foot candle. Then the illumination on the plane AC, which intercepts the same amount of light as AB, would be less than 1 foot candle (as the light is spread over a larger surface) in the ratio of AB to AC, which is the cosine of the angle ODF. Thus the illumination effective on any plane at a given point will be (candle power ÷ distance^2) $\times \cos\theta$, where θ is the angle between the direction of the ray and a perpendicular to plane considered.

a table on the next page, values of the illumination on horizontal planes at different heights and at different horizontal distances from a 1 candle power light and also the corresponding angles made by the light rays with the perpendicular to the plane.

The basis of most illumination calculations is the distribution curves of the lighting unit, some of which have been shown. The distance from the center to any point on the curve is directly

Intensity of Illumination in Foot Candles on Horizontal Planes for Points at Various Distances from a Light Source of 1 Candle Power. Angle Between Light Ray and Line Perpendicular to Plane Illuminated.

Horizontal Distance in Feet from Point Directly Under Light Source to Point Where Intensity of Illumination is Desired.

Height of Light Source in Feet Above Plane Illuminated	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
4	0° 0′ .06250	14° 2′ .05707	26°34′ .04472	36°52′ .03200	45° 0′ .02210	51°20′ .01524	56°19′ .01066	60°15′ .00764	63°26′ .00559	66° 2′ .00419	68°12′ .00320	70° 1′ .00249	71° 34′ .00198	72°54′ .00159	74° 3′ .00130	75° 4′ .00107	75°56′ .00090	76°46′ .00075	77°28′ .00064	78° 7′ .00055	78°42′ .00047
5	0° 0′ .04000	11°19′ .03771	21°48′ .03202	30°58′ .02522	38°40′ .01904	45° 0′ .01414	50°11′ .01050	54°28′ .00785	58° 0′ .00595	60°57′ .00458	63°26′ .00358	65°34′ .00283	67°23′ .00228	68°58′ .00185	70°21′ .00152	71°34′ .00126	72°39′ .00106	73°37′ .00090	74°29′ .00077	75°15′ .00066	75°56′ .00057
6	0° 0′ .02778	9° 28′ .02673	18°26′ .02372	26°34′ .01987	33°42′ .01600	39°48′ .01260	45° 0′ .00982	49°24′ .00766	53° 8′ .00600	56°19′ 00474	59° 3′ .00378	61°23′ .00305	63°26′ .00249	66°13′ .00205	66°48′ .00170	68°12′ .00142	69°27′ .00120	70°34′ .00102	71°34′ .00088	72°28′ .00076	73°18′ .00066
7	0° 0′ .02041	8° 8′ .01980	15°57′ .01814	23°12′ .01585	29°45′ .01336	35°32′ .01100	40°37′ .00893	45° 0′ .00722	48°49′ .00583	52° 7′ .00473	55° 1′ .00385	57°31′ .00316	59°45′ .00261	61°41′ .00218	63°26′ .00183	64°59′ .00154	66°23′ .00131	67°37′ .00113	68°45′ .00097	69°46′ .00084	70°43′ .00074
8	0° 0′ .01563	7° 8′ .01527	14° 2′ .01427	20°33′ .01283	26°34′ .01118	32° 0′ .00953	36°52′ .00800	41°10′ .00667	45° 0′ .00552	48°22′ .00458	51°20′ .00381	53°59′ .00318	56°19′ .00267	58°24′ .00225	60°15′ .00191	61°55′ .00163	63°26′ .00140	64°48′ .00121	66° 2′ .00105	67°10′ .00091	68°12′ .00080
9	0° 0′ .01235	6° 20′ .01212	12°32′ .01148	18°26′ .01054	23°55′ .00943	29° 3′ .00825	33°42′ .00711	37°52′ .00607	41°38′ .00515	45° 0′ .00437	48° 0′ .00370	50°42′ .00314	53° 8′ .00267	55°18′ .00228	57°15′ .00196	59° 3′ .00168	60°38′ .00146	62° 6′ .00126	63°26′ .00110	64°40′ .00097	65°46′ .00085
10	0° 0′ .01000	5° 43′ .00985	11°19′ .00943	16°42′ .00879	21°48′ .00801	26°34′ .00716	30°58′ .00631	35° 0′ .00550	38°40′ .00476	41°59′ .00411	45° 0′ .00354	47°43′ .00305	50°11′ .00263	52°26′ .00227	54°28′ .00196	56°19′ .00171	58° 0′ .00149	59°32′ .00130	60°57′ .00115	62°14′ .00101	63°26′ .00089
11	0° 0′ .00826	5° 12′ .00816	10°18′ .00787	15°15′ .00742	19°59′ .00686	24°27′ .00623	28°37′ .00559	32°28′ .00496	36° 2′ .00437	39°17′ .00383	42°16′ .00335	45° 0′ .00292	47°30′ .00255	49°46′ .00223	51°50′ .00195	53°45′ .00171	55°30′ .00150	57° 6′ .00132	58°34′ .00117	59°56′ .00104	61°12′ .00092
12	0° 0′ .00694	4° 46′ .00687	9° 28′ .00668	14° 2′ .00634	18°26′ .00593	22°37′ .00546	26°34′ .00497	30°15′ .00448	33°42′ .00400	36°52′ .00356	39°48′ .00315	42°31′ .00278	45° 0′ .00246	47°17′ .00217	49°24′ .00191	51°20′ .00169	53° 8′ .00150	54°49′ .00133	56°19′ .00119	57°43′ .00106	59° 3′ .00094
13	0° 0′ .00592	4° 24′ .00587	8° 45′ .00571	13° 0′ .00547	17° 6′ .00517	21° 2′ .00481	24°46′ .00447	28°18′ .00404	31°34′ .00366	34°42′ .00329	37°34′ .00295	40°14′ .00263	42°44′ .00235	45° 0′ .00209	47° 6′ .00187	49° 5′ 00166	50°54′ .00148	52°36′ .00133	54° 10′ .00119	55°38′ .00106	56°59′ .00096
14	0° 0′ .00510	4° 5′ .00506	8° 8′ .00495	12° 6′ .00477	15°57′ 00454	19°39′ .00426	23°12′ .00396	26°34′ .00365	29°45′ .00334	32°44′ .00304	35°32′ .00275	38° 9′ .00248	40°37′ .00223	42°53′ .00201	45° 0′ .00180	46°58′ .00162	48°49′ .00146	50°31′ .00131	52° 7′ .00118	53°37′ .00107	55° 1′ .00096
15	0° 0′ .00444	3° 49′ .00442	7° 36′ .00433	11°19′ .00419	14°56′ .00401	18°26′ .00380	21°48′ .00356	25° 1′ .00331	28° 4′ .00305	30°58′ .00280	33°42′ .00256	36°15′ .00233	38°40′ .00212	40°55′ .00192	43° 1′ .00174	45° 0′ .00157	46°51′ .00142	48°34′ .00129	50°11′ .00117	51°43′ .00106	53° 8′ .00096
16	0° 0′ .00391	3° 35′ .00388	7° 8′ .00382	10°37′ .00371	14° 2′ .00357	17°25′ .00339	20°33′ .00321	23°38′ .00300	26°34′ .00280	29°23′ .00259	32° 0′ .00238	34°30′ .00219	36°52′ .00200	39° 6′ .00183	41°10′ .00167	43° 9′ .00152	45° 0′ .00138	46°45′ .00126	48°22′ .00115	49°53′ .00105	51°20′ .00095
17	0° 0′ .00346	3° 22′ 00344	6° 42′ .00339	10° 0′ .00331	13°15′ .00319	16°24′ .00306	19°26′ .00290	22°23′ .00274	25°12′ .00256	27°54′ 00239	30°28′ .00222	32°54′ .00205	35°13′ .00189	37°24′ .00174	39°29′ .00159	41°25′ .00146	43°16′ .00134	45° 0′ .00122	46°38′ .00112	48°11′ .00103	49°39′ .00094
18	0° 0′ .00309	3° 11′ 00307	6° 20′ .00303	9° 28′ .00297	12°32′ .00287	15°32′ .00276	18°26′ .00264	21°14′ .00250	23°55′ .00236	26°34′ .00221	29° 3′ .00206	31°26′ .00192	33°42′ .00178	35°49′ .00165	37°52′ .00152	39°48′ .00140	41°38′ .00129	43°22′ .00119	45° 0′ .00109	46°33′ .00100	48° 0′ .00092
19	0° 0′ .00277	3° 1′ .00276	6° 0′ .00273	8° 58′ .00267	11°53′ 00260	14°45′ .00251	17°31′ .00240	20°13′ .00229	22°50′ 00217	25°21′ .00205	27°45′ .00192	30° 4′ .00180	32°17′ .00167	34°23′ .00156	36°23′ 00145	38°17′ .00134	40° 6′ .00124	41°49′ .00115	43°27′ .00106	45° 0′ .00098	46°29′ .00090
20	0° 0′ 00250	2° 52′ .00249	5° 43′ .00246	8° 32′ .00242	11°19′ .00236	14° 2′ 00228	16°42′ .00219	19°17′ 00210	21°48′ .00200	24°14′ .00190	26°34′ .00179	28°49′ .00168	30°58′ .00158	33° 2′ .00147	35° 0′ .00137	36°52′ .00128	38°40′ .00119	40°22′ .00111	41°59′ .00103	43°32′ .00095	45° 0′ .00088

proportional to the candle power in that direction, which may conveniently be read off by the aid of the equally spaced concentric circles on the diagram.

One of the first points to be considered in designing a lighting installation is the desired intensity of illumination.

The table here given shows the proper illumination for various classes of service.

TABLE OF REQUIRED INTENSITY OF ILLUMINATION

	Foot candles required		Foot candles required
Auditoriums, theatres	1 to 3	General offices	3 to 4
Bookkeeping	3 " 5	Offices with desk lights	1½ " 2½
Corridors, halls	½ " 1	Post offices	2 " 5
Depots, halls, churches	¾ " 1½	Reading	1 " 3
Draughting rooms	5 " 10	Residences	1 " 3
Desk lighting	2 " 5	Stores (light goods)	2 " 3½
Engraving	5 " 10	" (dry goods)	4 " 6
Factories (individual drops)	2 " 3	" (clothing)	4 " 7
Factories (no individual drops)	4 " 5	Store windows	5 " 20
Hotel halls	1 " 1½	School rooms	2 " 3
" rooms	2 " 3	Saloons, cafes	2 " 5
Offices, waiting rooms	1¼ " 2½	Stations (waiting rooms)	1½ " 2½
Private offices	2 " 3	Train sheds	1½ " 2
		Ware houses	1½ " 2

Color of Walls and Ceiling.—The effect of the color of the side walls and ceiling is one which must be considered in designing illumination. There is always some reflected illumination in a room and every object assumes the color of the light which it reflects. Hence, the colored rays reflected from the walls tend to tint all the objects in the room. Since the lighter colors reflect more light, the resulting illumination will be thereby considerably increased.

The following table gives approximate coefficients of reflection from wall papers, that is, the amount of reflected light expressed as a proportion of the total light received by the surface. These figures are based on the use of incandescent lamps.

Reflection Coefficients.

Kind	Color	Coefficient of reflection K	$\frac{1}{1-K}$
Plain ceiling	Faint greenish	.53	2 13
	Light yellow	.49	1 96
	Faint pinkish	.43	1 75
	Pale bluish white	.31	1.45
	Light gray green	.23	1.30
Crepe	Medium green	.19	1.23
	Medium red	.08	1.09
	Deep green	.06	1 06
Cartridge	Medium light buff	.44	1.79
	Light blue	.20	1.25
	Pale pink	.19	1.23
	Light green	.18	1.22
Striped ("two-toned")	Deep cream silvery	.57	2.32
	Light strawberry pink	.43	1 75
	Light green	.26	1.35
	Medium red	08	1 09
Miscellaneous	Light gray	.38	1.61
	Light green and gold minute (much gold) figuring)	28	1.39

For practical problems, the increase in illumination over that calculated from the distribution curve or illumination table for the unit considered is about as indicated in the table on the next page. These data are deduced from tests reported by Messrs. Lansing and Rolph before the Illuminating Engineering Society.

TABLE SHOWING INCREASE OF ILLUMINATION*

Ceiling	Walls	Increase over calculated
Very dark	Very dark	0%
Medium	Very dark	15%
Medium	Medium	40%
Very light	Very dark	30%
Very light	Medium	55%
Very light	Very light	80%

CHAPTER 138

Gas Appliances

There is a great multiplicity of gas appliances from which a selection can be made to meet the requirements of almost any service. For domestic use, these appliances are employed for:

1. Illumination.
2. Cooking.
3. House heating.
4. Hot water supply, etc.

Combustion and Burners.—The temperature of all combustible materials must be raised to a critical temperature, definutely known as the "point of ignition." The oxygen necessary for combustion of gas is obtained from the air. The efficiency of the work done will depend largely upon the method and place of supplying this air, as this will determine the character of the flame and also the temperature of the flame.

The usual open flame burner, still in use for illumination in some houses, illustrates a condition where all the air is obtained at the surface of the flame. In consequence of this the flame is large, as the absorption of oxygen in this case takes place only at the surface of the flame; hence there is no combustion (or burning) until the hydrogen and carbon in the gas have been able to secure sufficient oxygen to form a complete chemical compound two volumes of hydrogen uniting with one volume of oxygen

to form water and one volume of carbon uniting with two volumes of oxygen to form carbon dioxide.

There is considerable heat radiated into the surrounding air from an open flame burner; this tends to reduce the temperature of the flame so that very little useful mechanical (or industrial) heating could be obtained from a flame of this character except under special conditions.

Professor Bunsen of the University of Heidelberg noticed that, when a

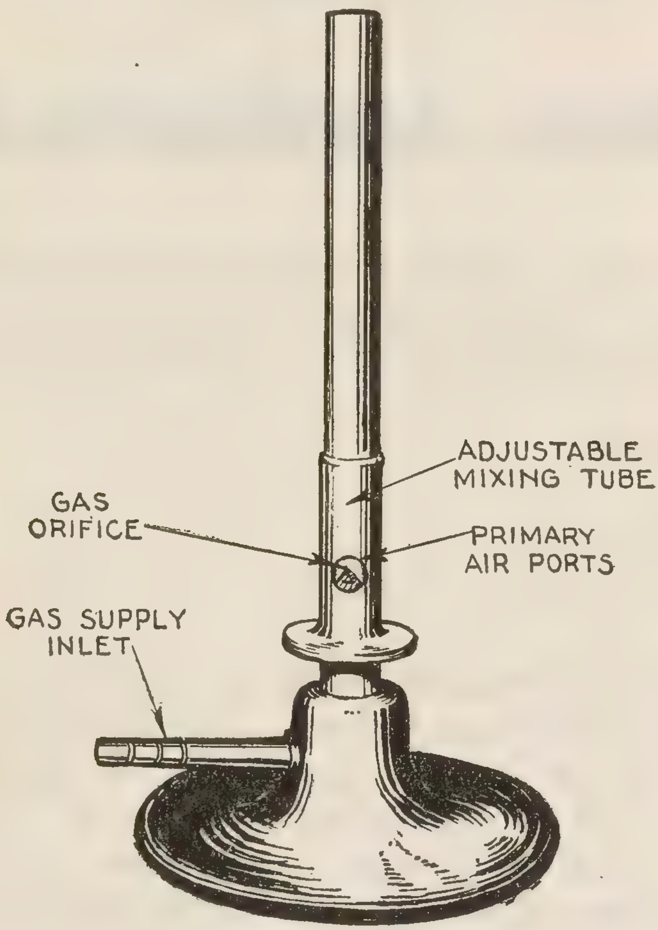


FIG. 9,034.—Bunsen burner. In ***operation***, gas passes through the gas orifice into the mixing tube, drawing in primary air through the primary air ports, which are adjustable by means of a ported sleeve, which turns on the mixing tube to open or close the air passage.

draft of air strikes the surface of an open gas flame, the flame is reduced in size and becomes non-luminous; this suggested to him the idea of pre-mixing a portion of the required air before combustion took place. The elimination of free carbon from the flame by the pre-mixing of air permits the flame to be placed much closer to the vessel to be heated, thus reducing the amount of ventilation over the flame and decreasing the loss by radia-

tion. It is important that high flame temperature be maintained for some industrial purposes.

In the Bunsen burner, where a certain amount of oxygen (air) is pre-mixed before ignition, the flame is very short because the combustion is very rapid. In cases when the supply of air is in excess of that required, the mixture is "thin" or made lean, and the flame flashes back. The usual remedy for this is to decrease the air supply. The greater amount of air which may be pre-mixed with the gas without danger of flash back, the smaller and more efficient will be the flame for most purposes.

If illuminating gas be heated to a high temperature, the hydro-carbon gases and vapors contained in the gas are, in the absence of air, decomposed, forming free carbon and hydrogen. In the ordinary luminous flame some

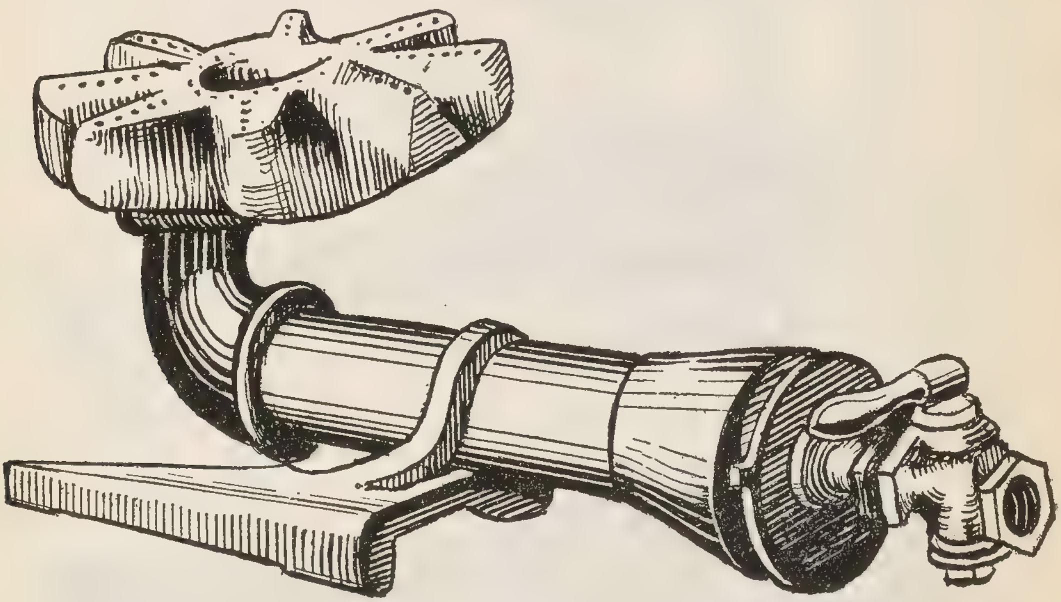
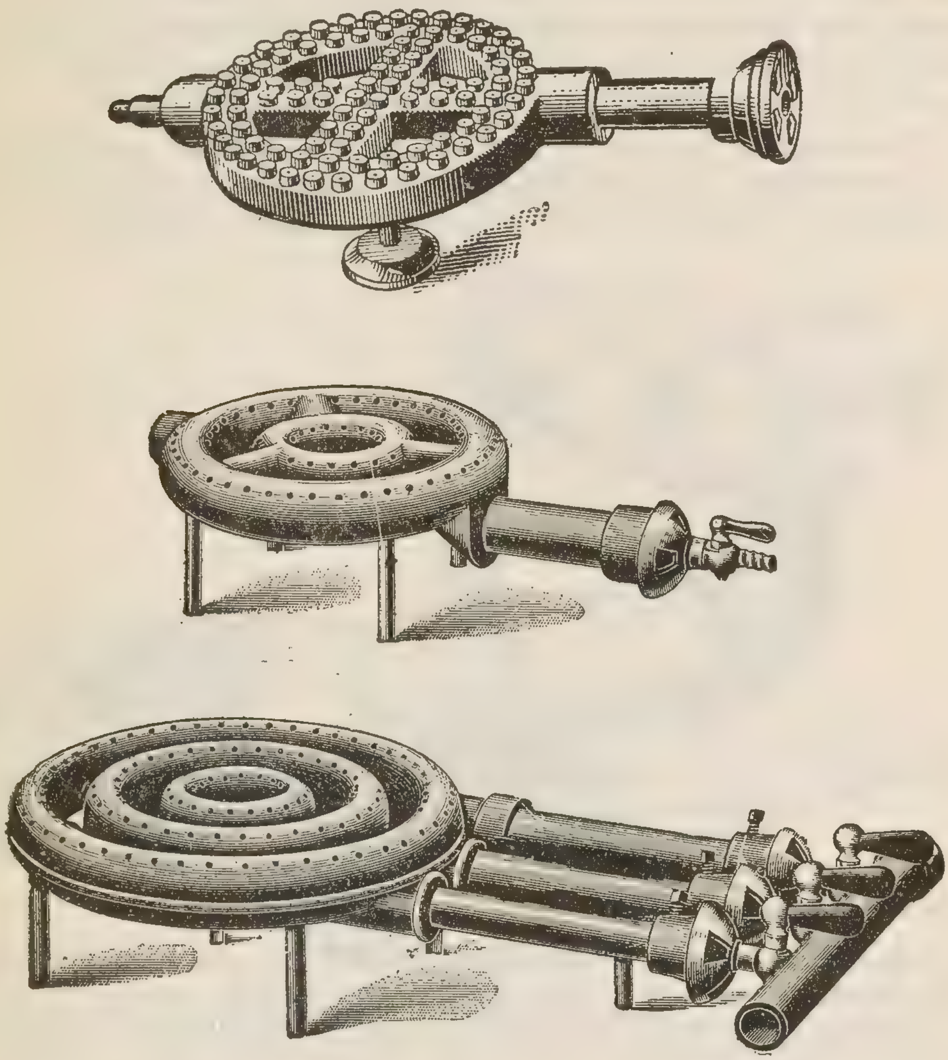


FIG. 9,035.—Star burner.

of the carbon is heated to incandescence and this furnishes the light. In the Bunsen flame this is prevented by the primary air, as stated above. It does not smoke or deposit free carbon on a cool surface. If a cold object such as a piece of sheet metal, be held in a luminous flame, a black film of soot is formed.

This is due to the fact that the flame is cooled, depositing some of its unconsumed carbon as lamp black on the surface of the object. If the same object or a similar one be held in the properly adjusted flame of a Bunsen burner, no such deposit is formed, nor can it be formed. If, however, the object be sufficiently chilled, some of the gas will escape unburned.

The construction of a Bunsen burner is shown in fig. 9,034. The air is *pre-mixed* with the gas before ignition is called the *primary air*, as distinguished from the air which flows in around the flame enabling combustion to become complete, called the *secondary air*.



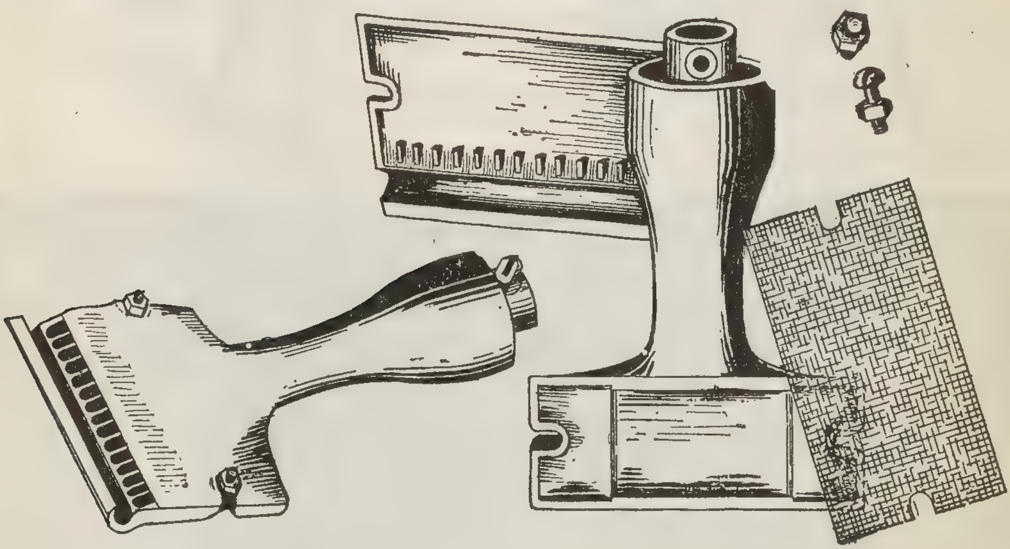
FIGS. 9,036 to 9,038.—Various forms of ring burner.

For heating there are four styles of atmospheric burners available for use:

1. Ring.

2. Star.
3. Pipe.
4. Pedestal.

Examples of these types are shown in the accompanying cuts. The selection of any particular style of burner is governed by the nature of the work to be done and the shape and character of the surface to which the heat is applied.



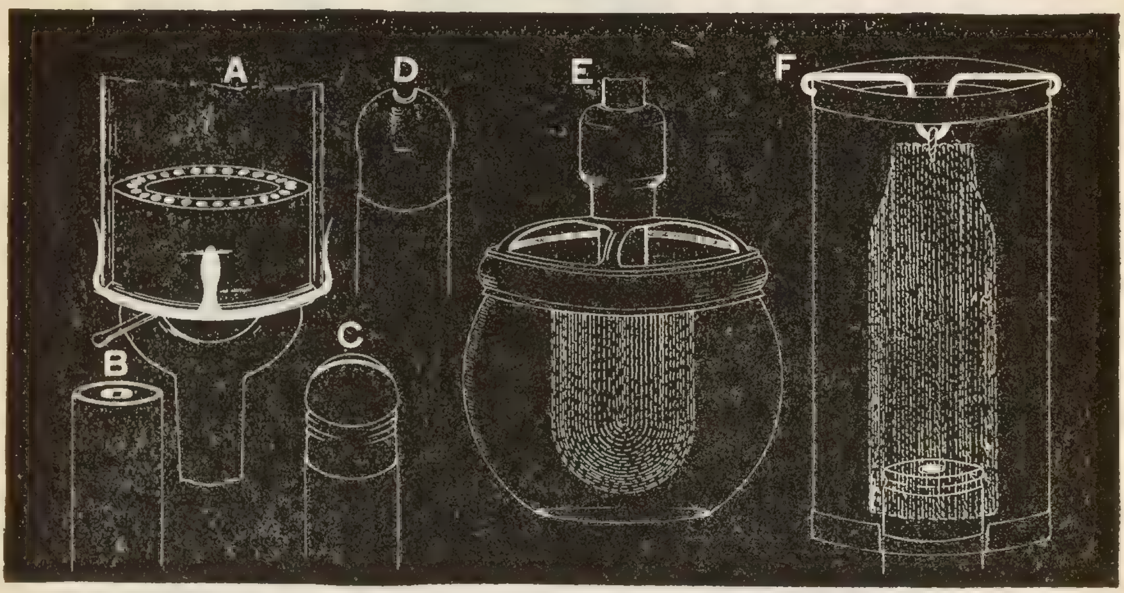
Figs. 9,039 to 9,044.—Pedestal burner.

The burner should be located as closely as possible to the surface to be heated; however, this minimum distance is fixed by the proper combustion of the flames, the latter depending in turn upon the circulation of the secondary air. For top burner work and the heating of small utensils the ring and star burners are preferred because they conform more nearly to the shape of the vessels than do other forms of burners. Of these two burners, experiments seem to show that when given equally good design, for instance, in the form and size of the air mixers, the drilled ring burners possess a slightly greater efficiency, that is, enable the larger proportion of the total heat given by the gas consumed to be utilized in useful work. The star shaped burner (fig. 9,035) offers the advantage over the ring burner in that it is possible to drill more ports on its surface and thus a more even distribution and greater capacity are obtained.

The advantage of the ring burner consists in a better supply of secondary air to all parts of the flame, owing to the fact that the air is free to rise on the inside of the circle of ports as well as on the outside, whereas in the star burner, unless it be very well designed, the access of the secondary air to the gas issuing from the central portions of the burner is very much obstructed.

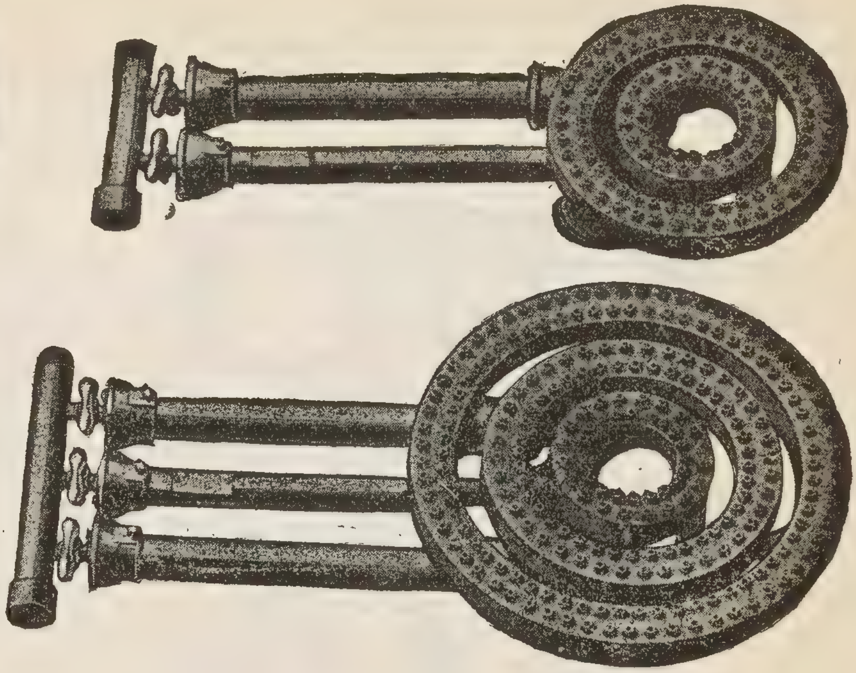
For spherical surfaces the ring burner should be used, because the flames burning from the circles of ports will nearly conform to the surface of the

FIG. 9,045.—Pipe burner.

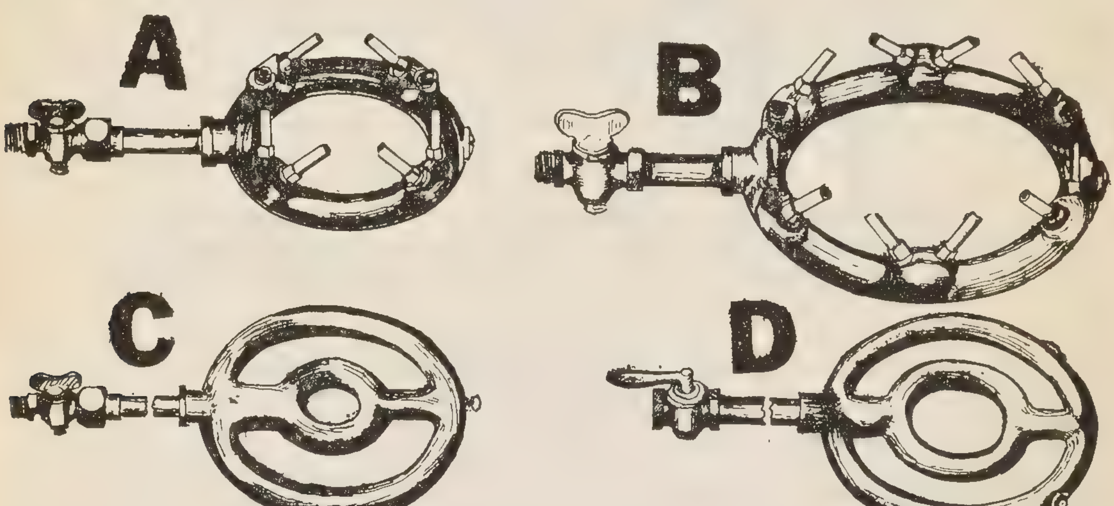


FIGS. 9,046 to 9,051.—Various gas tips. A, angular; B, flat; C, spherical; D, horned; E, vertical welsback; F, inverted welsback.

vessel than will either a star shaped or pipe burner. This will allow the ring burner to be brought nearer to the vessel than either of the other two. In certain forms of water heaters and steam boilers, where a large quantity of gas is used and a relatively small space is provided, the pedestal type of burner (fig. 9,039) is used. The arrangement of these burners is easily made to conform to the surfaces to be heated and at the same time to operate over a wider range of gas consumption than will the other forms of burners.



Figs. 9,052 to 9,054.—Various Combustion Utilities low power atmospheric concentric burners. Fig. 9,052, single; fig. 9,053, double; fig. 9,504 triple burner.



Figs. 9,055 to 9,058.—Various Barber gas burners. Fig. **A,** type "S" jet burner; fig. **B,** type "Z" jet burner; fig. **C,** type "G" burner; fig. **D,** type "L" burner. Types "S" and "Z" burners are especially adaptable to hot water heaters, small steam boilers, floor furnaces, coffee urns, liquid tanks, coal stoves and ranges and similar appliances, having combustion chambers 6 ins. or more deep. Types "G" and "L" burners are adaptable to small steam boilers, vulcanizer boilers, liquid tanks, metal pots, candy stoves, coal stoves, hot water heaters, french ranges and similar appliances having combustion chambers, or fire boxes, 9 ins. or more deep.

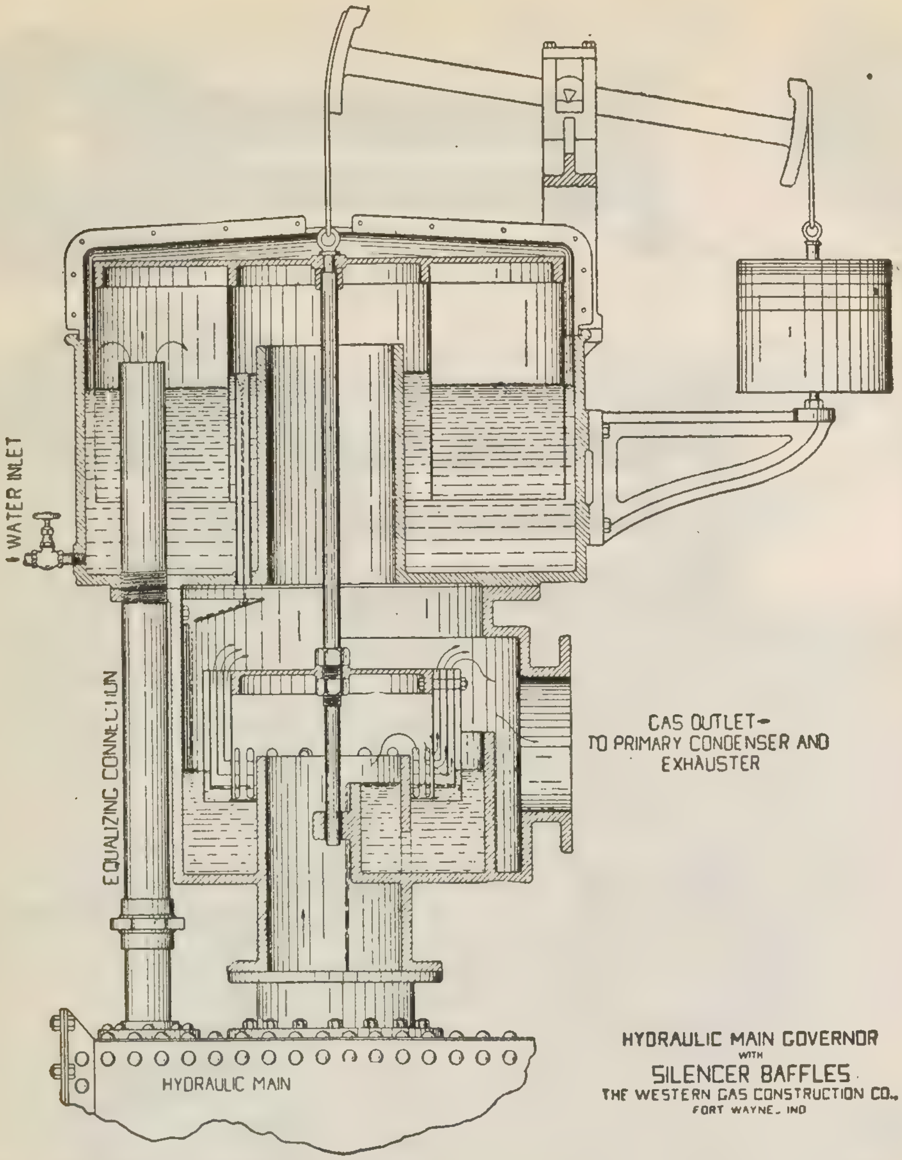


FIG. 9,059.—Western retort house governor. ***In operation,*** a very small change in the gas pressure in the hydraulic main communicated through the vertical pipe to the space under the large float, will cause an immediate movement of the bell or valve. To secure dependable results, however, the level of the tar in which the bell is sealed off must not materially change; that is, it must not be blown out by a sudden rush of gas. To prevent this, "silencer plates" are provided that give free flow to all gas coming from under the serrated edge of the bell, without any disturbance of the surface level. The installation of this governor will permit the seal of the dip pipes to be reduced to the minimum, increasing the quantity and quality of the gas made.

NOTE.—***Tar Stills.*** Many plants could advantageously install a tar still from which the products are light oils, middle or carbolic oils, heavy or creosote oils and pitch. For best results, the still must be designed to suit the tar, and the amount and specifications of the products desired. Smaller plants can often profitably install a still to prepare tar and pitch for roofing felt and tar paper, and make paving pitch.

On large surfaces of almost any shape, such as may be found on tanks, trays, ovens, etc., the drilled pipe burner (fig. 9,045) is used. With these burners an even distribution of the heat over the entire surface may be obtained. If either the star or ring burner were used for this class of work it would be almost impossible to heat the vessel evenly, as over heating directly above the burners would result.

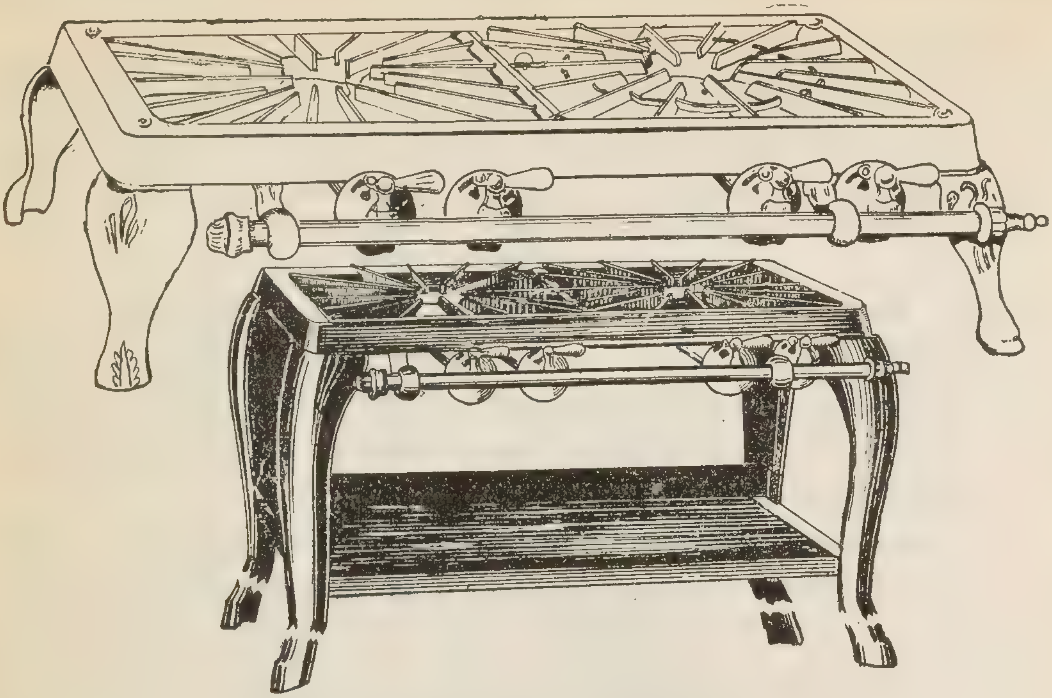
Burner Capacity.—In determining the burner capacity for coal burning appliances it is necessary to provide sufficient burner capacity, properly spread in the fire box, that the heat unit capacity, upon one ounce gas pressure, will be equivalent to the capacity of coal used in the same fire box.

The recognized standard coal capacity of fire boxes in appliances for domestic heating purposes, is approximately 5 lbs. per sq. ft. of grate area, per hour. To determine the coal capacity per hour, multiply the sq. ft. of grate area by 5. It may be conservatively estimated that each lb. of coal will develop 8,000 *B.t.u.* By multiplying the coal capacity per hour by 8,000 will give the *B.t.u.* developed. Then to determine in cu. ft. the amount of gas necessary to burn per hour to equal the coal capacity, divide the number of heat units required by the *B.t.u.* in the gas to be used (it is safe to figure natural gas at 1,000 *B.t.u.* and artificial gas at 500.)

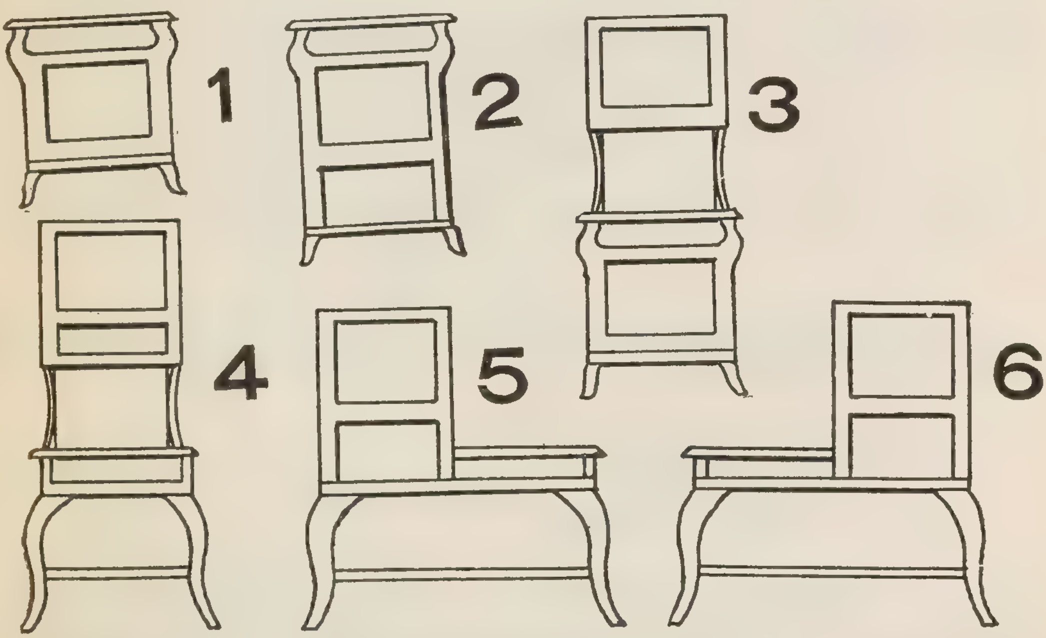
Example.—Determining burner capacity for a boiler having 7 sq. ft. of grate for burners consuming 41 cu. ft. of natural gas per hour.

$5 \times 7 = 35$ lbs. of coal per hour.
$35 \times 8{,}000 = 280{,}000$ *B.t.u.*
$280{,}000 \div 1{,}000 = 280$ cu. ft. of gas per hour.
$280 \div 41 = 6.8$ say, 7 burners.

Having determined the maximum gas capacity required, divide same by the capacity of the burner units to be used in construction of the special burner, which will determine the number of such units required in the burner layout. Having in mind that the heat must be distributed equally throughout the fire box, and also that the heat must be applied so as to strike the sections containing water, at the lowest point, the burner unit layout may then be made.



FIGS. 9,060 and 9,061.—Vulcan hot plate and laundry stove burners.



FIGS. 9,062 to 9,067.—Standard gas range types: **1** single oven; **2,** double oven; **3,** elevated type with one oven above and one oven below cooking top; **4** elevated type with both baking and broiling ovens above cooking top; **5,** cabinet, left oven; **6,** cabinet, right oven.

NOTE.—***In figuring burners*** for power boilers the actual combustion rate should be ascertained, or in the absence of definite information, a rate not less than 10 lbs. per sq. ft. of grate per hour should be assumed.

House Heating by Gas.—This can be accomplished by applying the gas to

1. Hot air furnaces.
   a. Pipe.
   b. So called pipeless.
2. Steam boilers.
3. Hot water boilers.

In a warm air system, some of the heat delivered by the furnace is radiated into the basement from the surface of the leader pipe. This heat is not entirely lost, however, because it tends to warm the floors of the rooms above and is useful in heating the basement also. It is usually safe to assume that 90% of the heat delivered to the heat pipes is finally brought into the rooms of the house provided that, 1, where leaders pass through unexcavated spaces under the house, they are double wrapped with corrugated asbestos paper, or equal insulation and, 2, the area of the air passages through the furnace is equal to or greater than the combined area of the heat pipes taken off the furnace in order to secure a positive flow of warm air through all of the heat pipes.

The following table gives the free areas and capacities of gas fired hot air furnaces.

Properties of Gas Fired Hot Air Furnaces

Heating Surface Sq. Ft.	Free Area Sq. In.	Gas Rate Cu. Ft. Per Hr.	B.t.u. Per Hr.	Contents Heated Cu. Ft.	No. Ducts	No. Rooms and Bath
121	452	125	62,000	8,500	5	5
242	990	250	125,000	17,000	12	10 & 2 baths
208	856	200	100,000	14,000	9	6
327	1,308	325	102,000	22,500	14	12 & 2 baths
416	1,522	400	200,000	24.000	16	14 & 2 baths

The normal gas rate is approximately 1 ft. of 570 *B.t.u* gas per hour per sq. ft. of heating surface.

Sizes of heat pipes based on the following capacities have operated

successfully in Portland, it being permitted that the area of the riser be not less than 80% that of the leader.

Capacity of leaders *B.t.u.* per sq. in. per hour:

First floor leaders	130 *B.t.u.*
Second " "	160 "
Third " "	190 "

The reader is referred to Bulletin No. 112 by Engineering Experiment Station of the University of Illinois. It is desirable to make the area of the returns equal to the combined area of the leaders or risers, as this tends towards a positive supply of heat to all rooms. The above data is for natural circulation.

In the following table for so called pipeless furnaces, the net free area of inner collar is taken as ⅔ the gross area on account of grating allowance:

Standard Sizes of Duplex Gratings

(for pipeless furnaces)

Opening Size	Approximate Extreme Size	Size Inner Collar	Approximate net area Inner Collar
20 x 22	22 x 24	14	103 sq. in.
22 x 24	24 x 26	16	134
24 x 27	26 x 29	18	170
30 x 30	32 x 32	22	253
30 x 36	32 x 38	24	302
35 x 35	37 x 37	26	354
36 x 36	38 x 38	28	410
40 x 40	42 x 42	30	472
45 x 45	47 x 47	36	689

From practice it has been found that the proper size grating to use for a furnace burning 100 cu. ft. of 550 *B.t.u.* gas per hour is a grating 24 in. × 26 in. extreme size and with 16 in. diameter inner collar. For a furnace burning 200 cu. ft. of gas per hour a grating 32 in. × 32 in. extreme size with 22 in. diameter inner collar should be used.

The following is an example of method that may be used in selecting size of pipeless furnace grating:

Assume that furnace capacity is one that burns 100 cu. ft. gas per hour. Then based on 550 *B.t.u.* gas and efficiency of 75%, at least 40,000 *B.t.u.* per hour, actually will be given to heating medium air. If room temperature be 70° F. and temperature of air at outlet be 160°, then each cu. ft. of air would bring $\frac{90}{55}$ or 1.8 *B.t.u.* into the room.

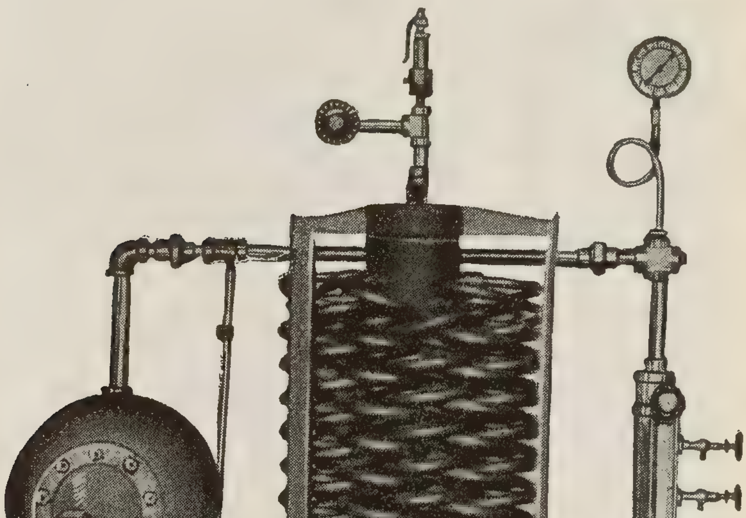


FIG. 9,068.—Ofeldt gas fired boiler for natural or artificial gas. Rated consumption 60 ft. of gas per horse power per hour. ***In operation***, water should be fed to boiler by gravity, city water, power driven pump or steam trap. Automatic water feed where water pressure is at least 5 lbs. greater than steam pressure. Working pressure up to 300 lbs.

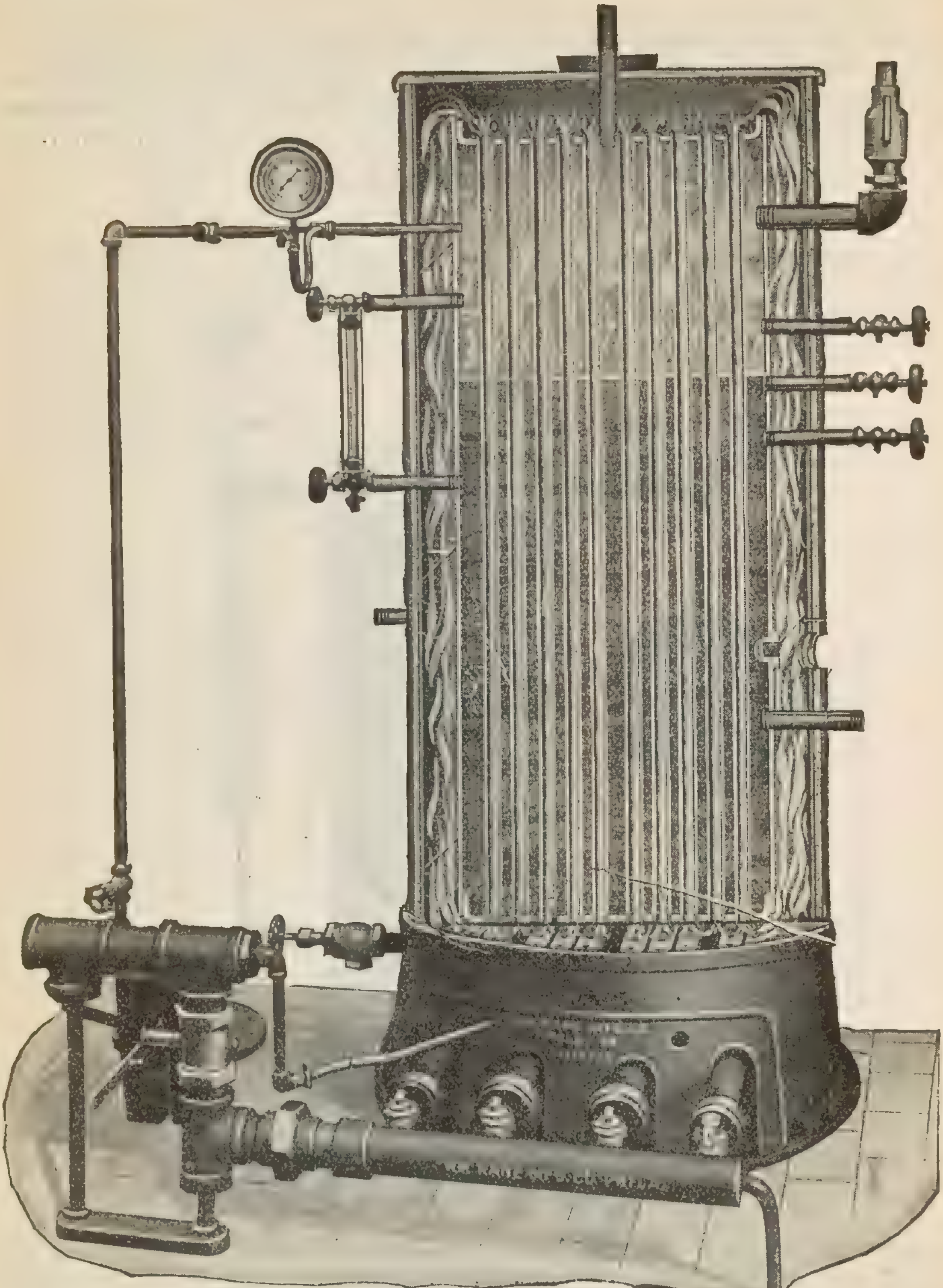


FIG. 9,069.—Kane automatic gas fired steam boiler.

Since furnace releases 40,000 *B.t.u.* to be conveyed into room it would therefore take $\frac{40,000}{1.8}$ or 22,000 cu. ft. of air per hour to deliver and dissipate this heat in room or building. This volume of air, 22,000 cu. ft. per hour, is equivalent to $\frac{22,000}{3,600} = 6.1$ cu. ft. per second.

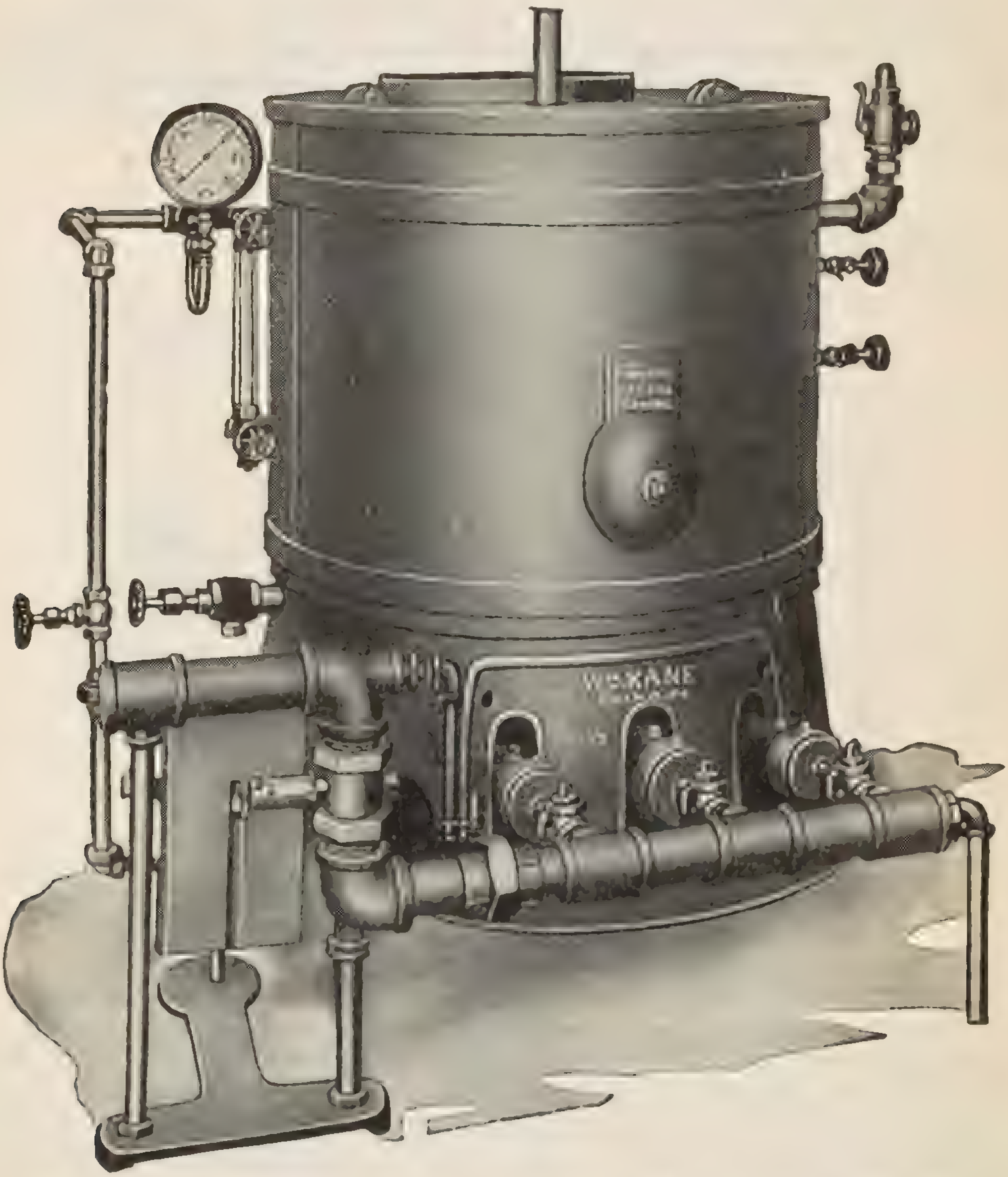
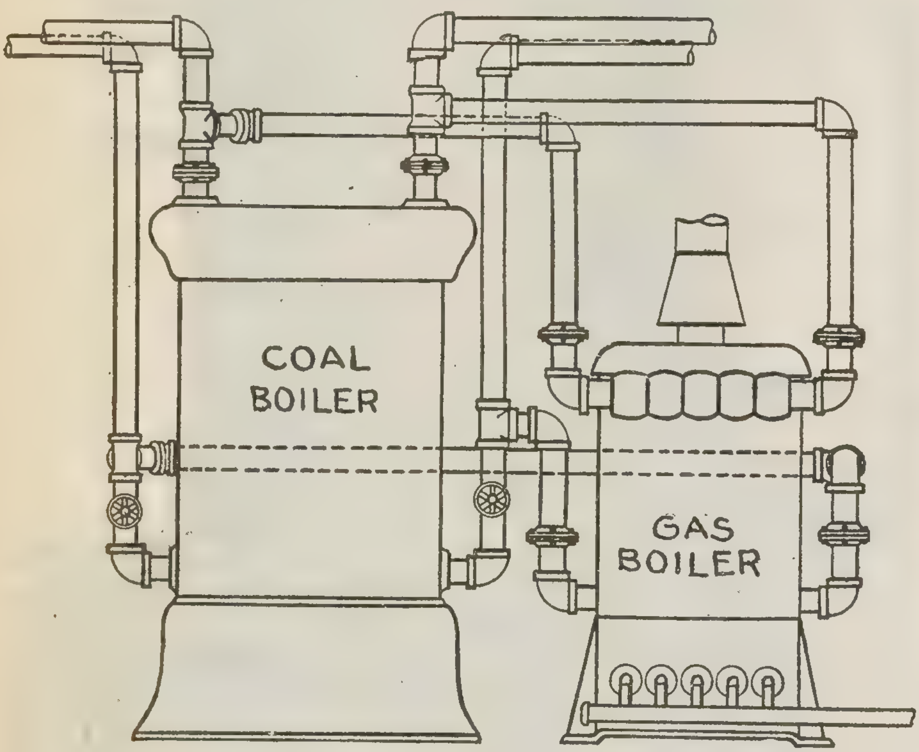


Fig. 9,070.—Kane low water line automatic gas fired steam boiler designed especially to operate on closed or direct return systems, where it is desirable or necessary to locate the boiler on the same floor level with the devices using steam, and yet have the condensation return to the boiler by gravity.

The velocity of the warm air as it leaves the register should not exceed 6 ft. per second, and using this value it is found that the net area of the warm air outlet should be $\frac{6.1}{6} = 1.02$ sq. ft. or not less than 1.02 or 144 or 146 sq. in. of free area.

Based on this free area it is seen from the table that the pipeless furnace grating necessary is one with inner collar for warm air outlet of 16 in. diameter, or 18 in. if permissible. If a grating be selected with less than 16 in. diameter inner collar, either the velocity will be too high or the air will be too hot for desirable results.



IG. 9,071.—Method of cross connecting hot water boilers.

As for the cold air return size, if the grating be used as listed in the table, this is amply provided for on basis of the selection of the inner collar size. Inadequate cold air return, or inlet, to any furnace will cause overheated furnace and excessive stack losses with resultant inefficiency and greatly lessened capacity.

The gas fired boiler is directly applicable to any type of heating system and will give satisfaction when properly proportioned for the load. Since

gas is an expensive fuel, certain details of installation become important. The boiler, piping and fittings should be covered with heat insulating material and the burners should be carefully adjusted.

Cross Connecting Coal and Gas Boilers.—Quite frequently when a customer has already a coal boiler in his home, it is desirable to leave the coal boiler in place, and to cross connect the gas boiler with it.

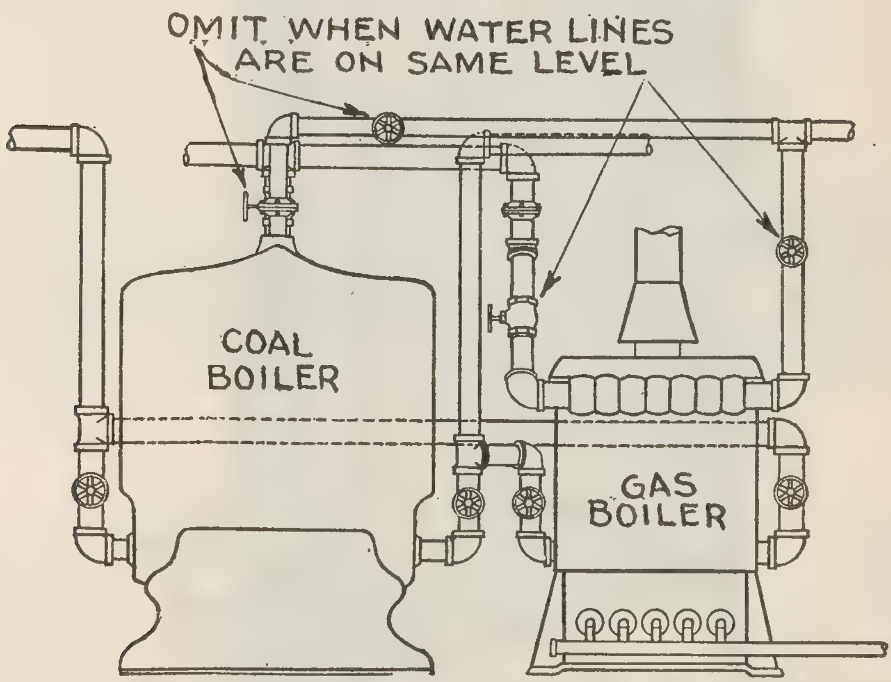


FIG. 9,072.—Method of cross connecting steam boilers when the water lines are not on the same level.

For small gas companies or any others where there is any possible chance of a shortage or failure of gas, it would seem to be good practice to encourage cross connecting as the customer would realize very little for a second hand coal boiler, and it is worth more to him as a safeguard against failure of his gas system than he would realize by selling it. It also produces a more secure feeling in the customer's mind when putting in gas fired house heating equipment, if he know that he can burn coal at any time he may desire. He then feels that he is not at the mercy of the Gas Company if the rates should be changed. There is almost no difference in the cost of

an installation, whether it be cross connected or displaced. Cross connection also gives the customer a means of disposing of papers, crating material, etc.

In hot water heating systems, it is necessary to valve off the return pipes

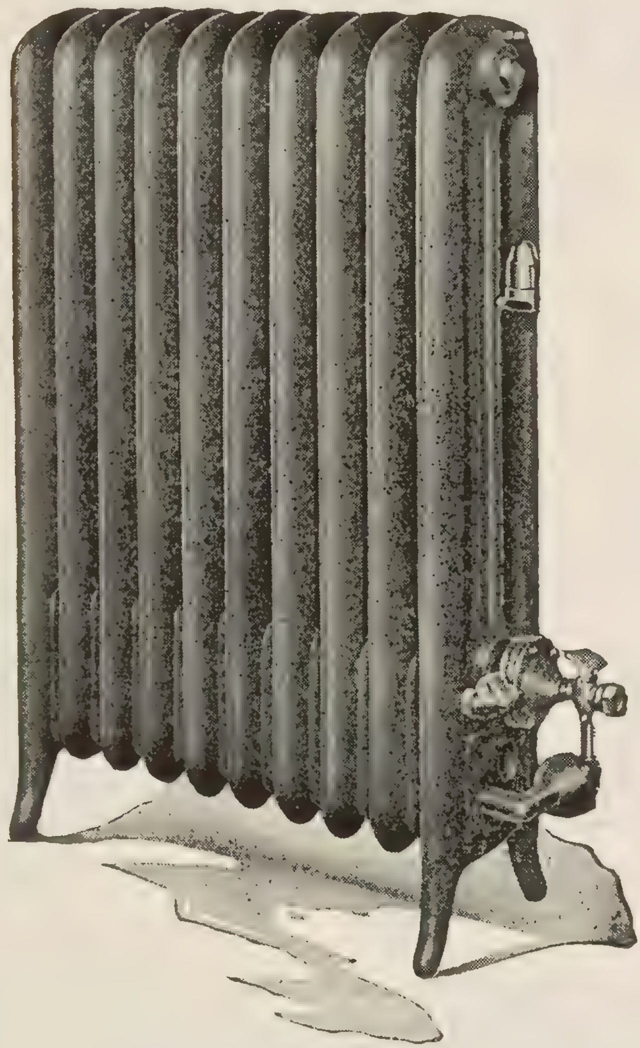
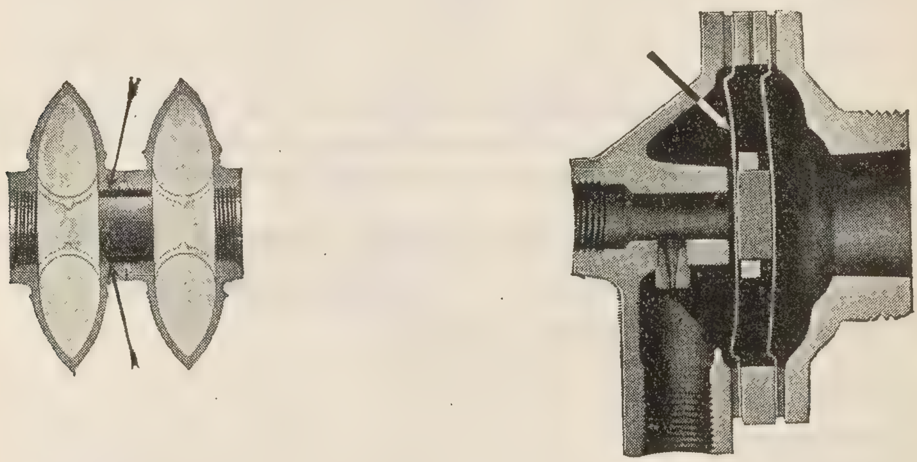


Fig. 9,073.—Wolf gas fired steam radiator with automatic control.

on the coal boiler, which prevents circulation through the latter when the gas boiler is in use. Since the gas boiler holds comparatively little water and is almost always insulated, no valves are needed on the return pipes.

Water Heating by Gas.—There are on the market various makes of so called *instantaneous** heaters.

Practically all manufacturers of this type of heater catalogue the following sizes, 2½, 3, 4, 6 and 8. The numbers indicate the approximate number of gals. per minute that can be heated through a 60 deg. F. rise. The heater size to be selected for any installation depends upon the maximum flow of hot water that it will be required to supply at any one time. This naturally means, how many hot water faucets may be operated



Figs. 9,074 and 9,075.—Wolf gas fired steam radiator details. Fig. 9,074, screw nipple construction; fig. 9,075, diaphragm regulator. The radiator sections are assembled with a *r* and *l* threaded malleable cast screw nipple as in fig. 9,075. The automatic diaphragm regulator (fig. 9,074) operates when the steam pressure reaches 5 lbs. to throttle the gas so as to maintain this pressure. More gas is used in starting to heat the room or rooms. This is automatically reduced to a minimum when the desired temperature in the room or rooms is reached.

at the same time and still each be expected to give a reasonable flow of water at a desirable temperature. The number of hot water fixtures that can be taken care of, therefore, depends upon the flow and as an average figure this can be taken at 2 gals. per minute per fixture.

The following table shows the maximum number of fixtures

*NOTE.—***The ridiculousness** of applying the word *instantaneous* to gas heating types of heater must be apparent to anyone having any knowledge of physics.

that can be in use at one time and be properly supplied by each size of heater.

Capacity of Heaters.

Number gals. per minute heated	Approximate gas cons. cu. ft. per hr.	Max. Number of Fixtures in use at one time
2½	150	1
3	180	1
4	240	2
6	360	3
8	480	4

As a rule, this means that the total number of hot water fixtures may be approximately four times the above allowance, as it is unusual for more than 25 per cent of the fixtures to be in use at any one time.

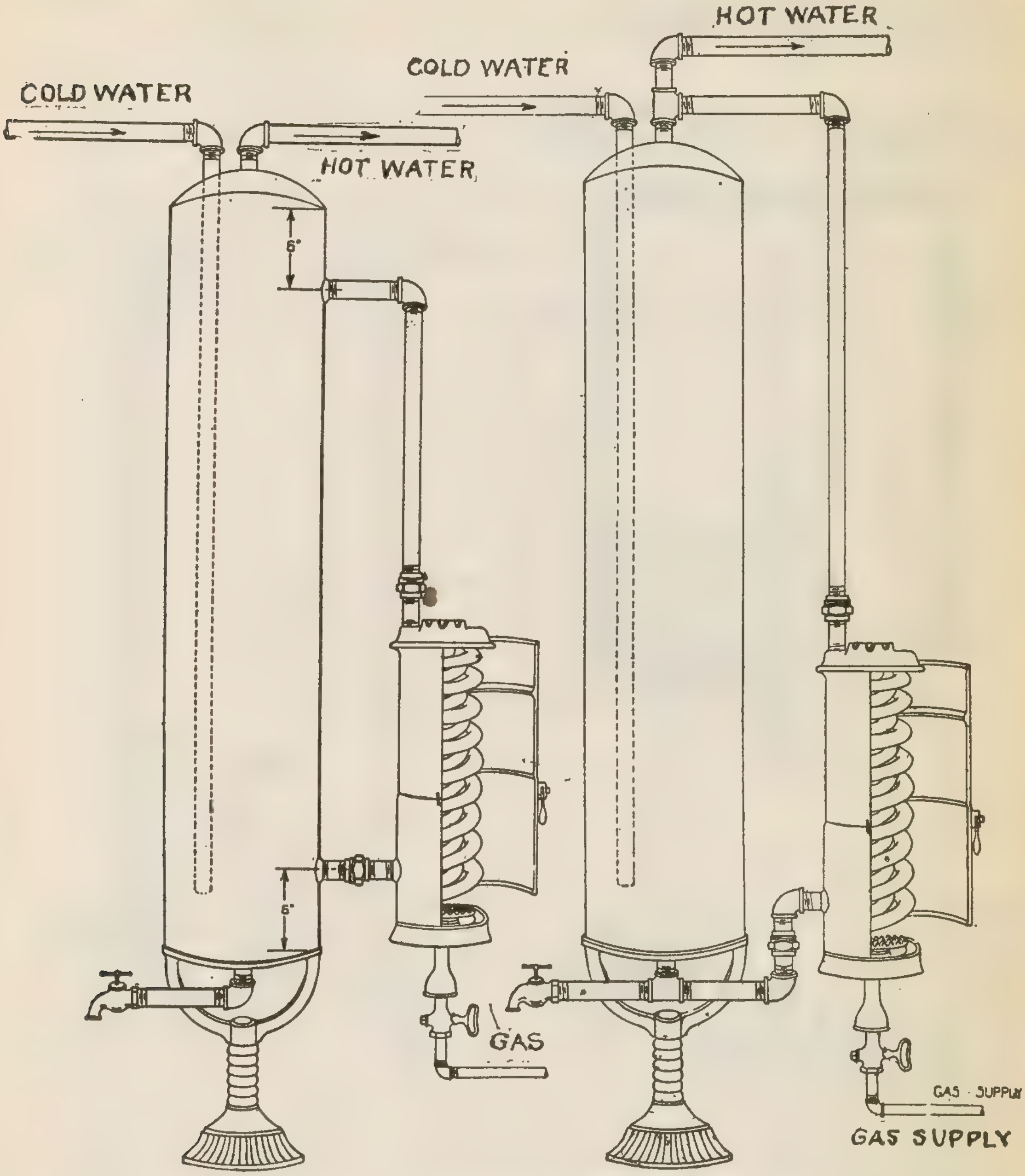
Installation of Gas Fired Water Heating Equipment.—There are numerous types of heating equipment and they may be divided into two general classes

1. Circulating.
   a. Non-automatic.
   b. Automatic.
2. So called instantaneous.

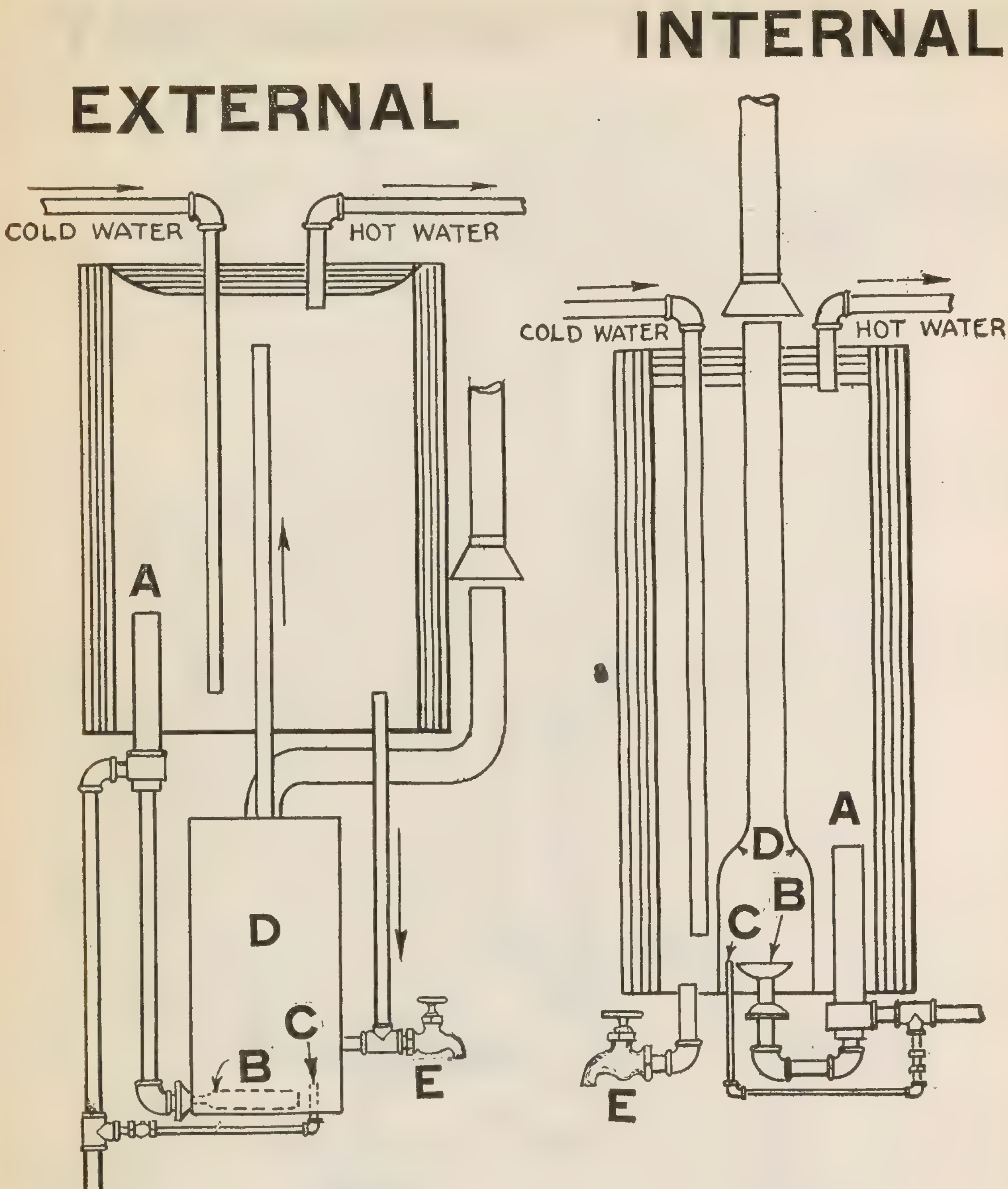
A correct installation results in safety, maximum life of equipment, maximum efficiency and minimum maintenance, accordingly the directions which follow for installing the various types should be carefully noted.

Small Circulating Non-Automatic Heaters.—A great many installations of this type of heater have given poor service, not because of the heater but due to the improper method of connecting it to the storage tank. This lack of general good service can be largely overcome if a few simple rules of installation be followed.

RIGHT WAY WRONG WAY



FIGS. 9,076 and 9,077.—Right and wrong way to connect small circulating water heaters. In fig. 9,076, the side tappings 6 ins. from top and bottom are now standard with range boiler manufacturers. If an adjustable tank coupling is to be used then it is advantageous to locate the top tapping as near the boiler crown as possible.



FIGS. 9,078 and 9,079.—Circulating non-automatic systems. Fig. 9,078 with external heater; fig. 9,079 with internal heater. Many makes of these heaters have come into wide use throughout the country for domestic purposes. They are very often used as auxiliary heaters in the winter time along with furnace and range water backs.

1. Make the circulating pipes between the heater and tank as free from bends and fittings as possible and use the largest practical pipe size (as a rule ¾″.)

2. Ream out the ends of all pipe under 1″ that is used on circulating lines between tank and heater.

The use of brass pipe on the hot water circulating line from heater to tank is recommended particularly for high temperature circulation.

3. Place unions as close to heater as possible on the hot and cold water circulating lines.

4. Place a sediment blow off valve or cock at low point under the tank.

5. The special side tappings as shown in fig. 9,076 are so superior to any other arrangement that their use is recommended without qualification.

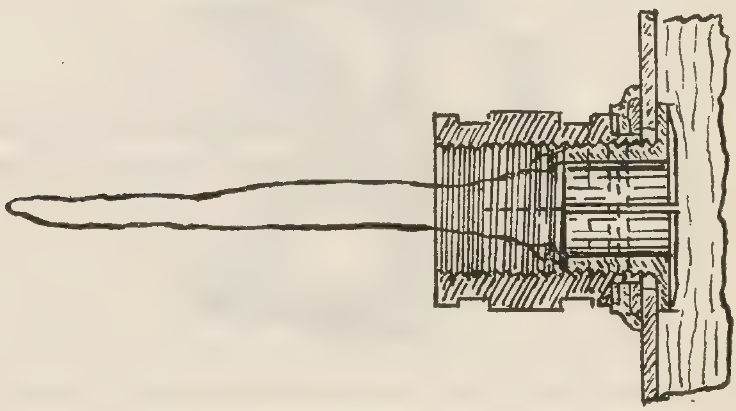


FIG. 9,080.—Adjustable tank coupling.

When used without a thermostat the lower tapping should be no less than 6 ins. above the bottom of the tank and the upper tapping no greater than 6 ins. from the top. This arrangement allows free circulation, which results in relatively large volume storage without overheating, it eliminates short circuiting of water through the heater and provides ample sediment storage below the circulating line, thus preventing sediment getting into the heating element. The special side tappings can easily be made on any kitchen boiler that is not so provided, by the use of the adjustable tank coupling shown in fig. 9,080, and the circular hack saw shown in fig. 9,081. The saw is used with any ordinary brace and will cut the desired size hole at any location. The adjustable coupling is then assembled in the hole and made firm. The whole operation is very simple and quickly accomplished.

6. Fig. 9,077 shows a heater connected to a tank without any special tappings, merely using the customary top and bottom tappings as supplied on ordinary kitchen tanks. This piping will never give the excellent results obtained from the arrangement shown in fig. 9,076. If for some reason the connections must be made as in fig. 9,077, the following precautions must be taken: *a*, get bottom of coil at least 6 ins. above bottom of tank; *b*, use a non by-pass T at top of tank on the hot water line from heater or else a 1 in. × ¾ in. T with the 1 in. outlet towards the tank and the T placed as close to the tank as possible.

7. Try to get consumer to cover the tank and all the hot water pipe. An asbestos or air cell covering of about 1½ in. thickness will quickly pay for itself.

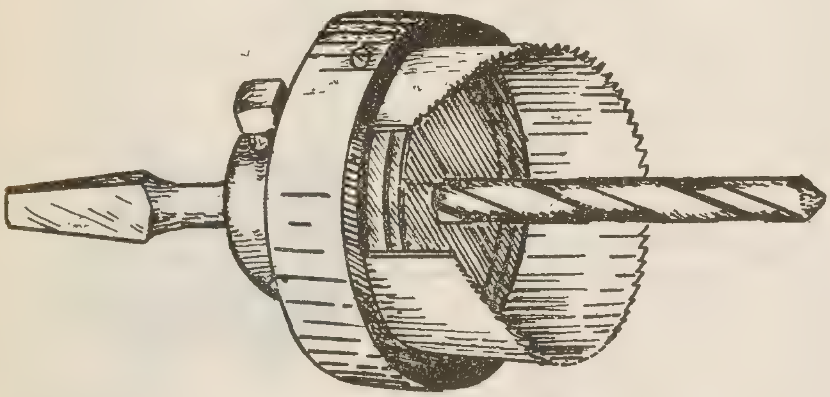


FIG. 9,031.—Combined drill and circular hack saw for making special tappings in storage tanks.

8. If a check valve or reducing valve be on the cold water supply pipe from the street to tank, then an automatic water relief faucet or valve should be installed on the hot water line.

Maintenance.—The burner should at all times be adjusted so that the gas flames are blue with no yellowish tips whatsoever. Be sure that the sharp inner cone of the flame does not touch any of the water heating surface. Occasionally the burner should be cleaned and any collection of dirt on the heating surface removed if full efficiency is to be maintained. At least once a month a pail of water should be drawn off through the drain cock under the tank.

Automatic Circulating Heaters.—This general class of water heaters may be divided into the following systems:

1. *Assembled heating systems.*

Consisting of an insulated tank (usually vertical) heater and thermostat, assembled by the manufacturer ready to install. The heating element is either a circulating heater attached to the tank with a simple run of pipe, or else a heating element located within the tank. The assembled units range in size from about 15 to 70 gals. storage capacity and 30 to 60 gals. per hour heating capacity. These systems are either shipped fully assembled or else knocked down, but with all parts fitted and ready for assembly.

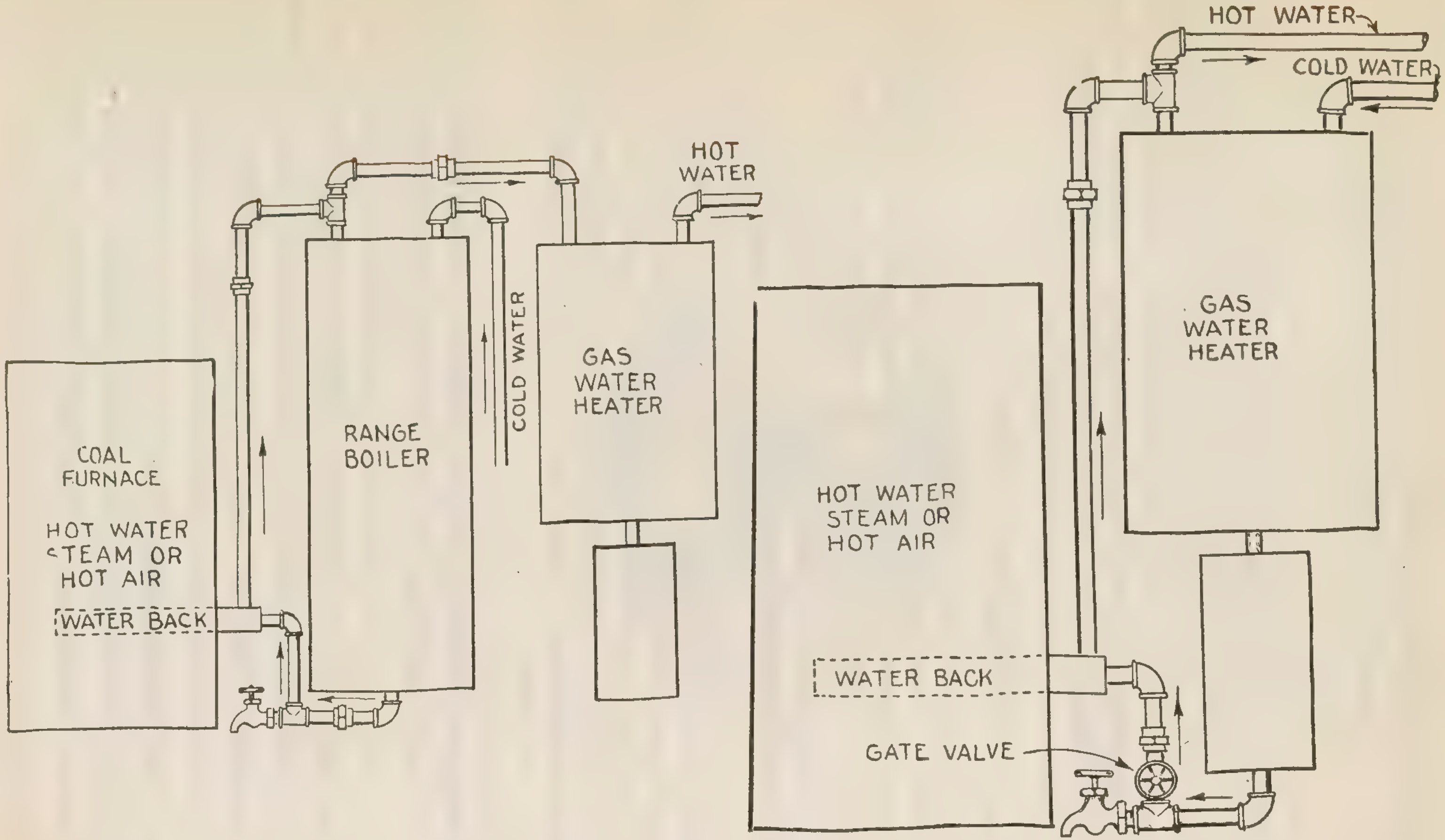
2. *Built up direct circulating systems.*

Consisting of a horizontal or vertical storage tank, a circulating heater and thermostat. The heaters for this purpose vary in capacity from the small circulating copper coil heater to large cast iron heating boilers with a capacity up to 1,000 gals. per hour. The storage tank capacity can be of any desired amount with the tank horizontal.

3. *Built up indirect steam systems.*

Consisting of a horizontal storage tank with steam coils in it, a low pressure steam boiler and thermostat. The boilers and tanks are available in the same capacities as Class 2. The temperature control can work directly on the gas supply or else on the steam supply from the boiler to the coil within the tank. In the latter method of control the steam pressure is then automatically maintained by the steam pressure regulator acting on the gas supply.

Points Common to all Storage Systems.—The most important item to pay attention to is the proper location of the appliance. As this is an automatic appliance it should be flue connected and the heater should, therefore, be placed so that a short simple flue is possible. An effective back draft diverter should be placed in the flue near the heater. The next important thing in determining location of the heater is the hot water house pipe. Make the connection from the tank outlet to the hot water pipe as direct as possible and favor that portion of the house where most of the fixtures are located by placing heater as nearly under main riser as possible.



FIGS. 9,082 and 9,083.—Methods of connecting a water back to a small circulating system both with and without a range boiler The system shown in fig. 9,082 is not as desirable as the reheating system (fig. 9,083) for the reason that the water is liable to become overheated in the insulated boiler of the gas heated unit during cold weather, unless a small pipe is used in the fire pot of the furnace. A gate valve must be placed in the circulating pipe, as indicated, and this valve should be closed whenever the furnace is not in use in order to prevent the hot water from circulating through the water back and thus wasting gas.

For economy of operation avoid the use of house circulating lines whenever possible. In the average building under four floors in height, it is absolutely unnecessary and a tenant would never know whether the water was circulating or not.

In many small dwellings there is no circulating return line, but if there be one, it can usually be cut off by closing a valve, on the return end in the cellar. The following table shows the maximum length of pipe from the tank to the most remote fixture that can be satisfactorily used without circulation:

Pipe Size	Linear Ft.
½ in.	150
¾ "	90
1 "	50
1¼ "	30

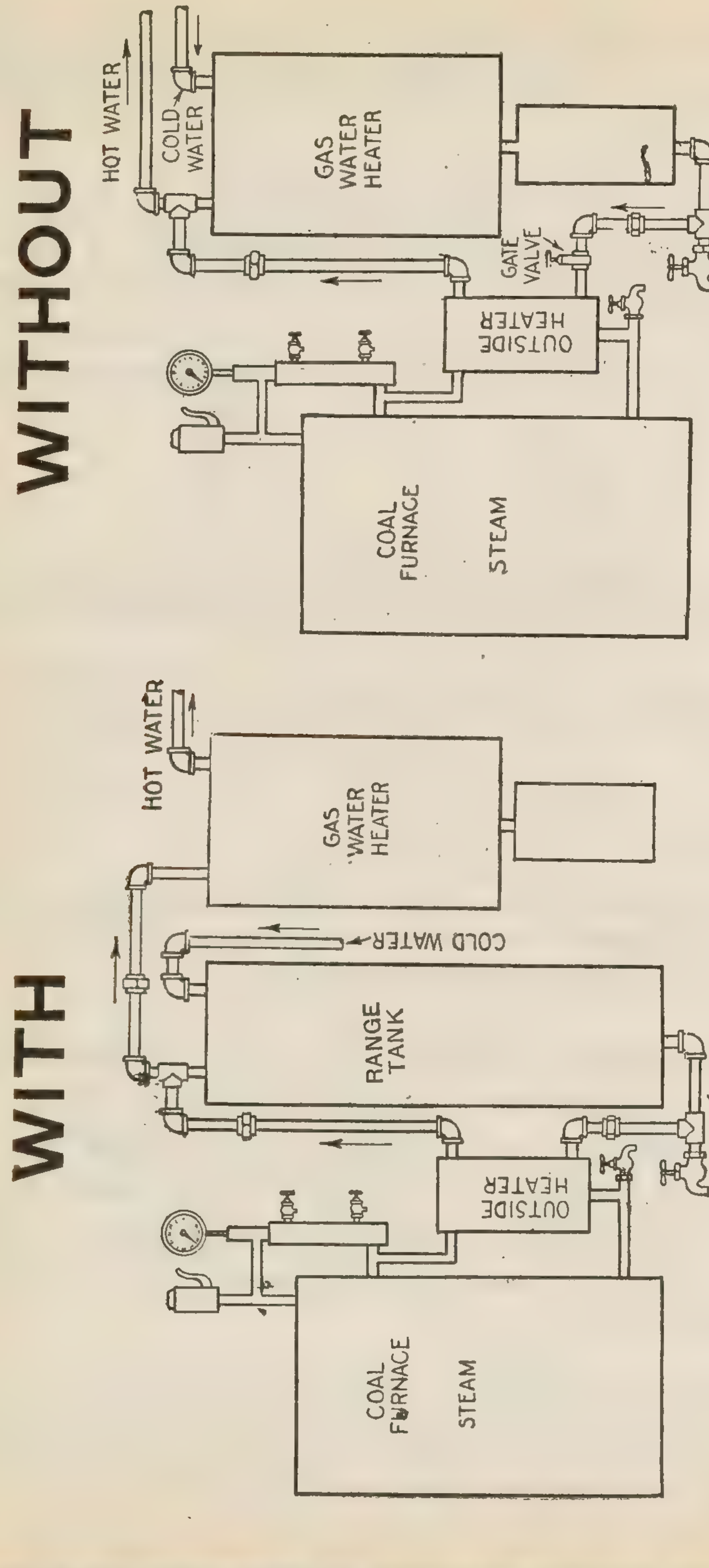
The value of insulating all hot surfaces cannot be too strongly emphasized. The following minimum coverings are recommended for various temperatures:

Tank Temperature	Thickness of Covering	Approx. Sav. cu. ft. of Gas per mo. per sq. ft.
120° F.	1 in.	85
140° F.	1½ "	125
160° F.	2 "	160
180° F.	3 "	200

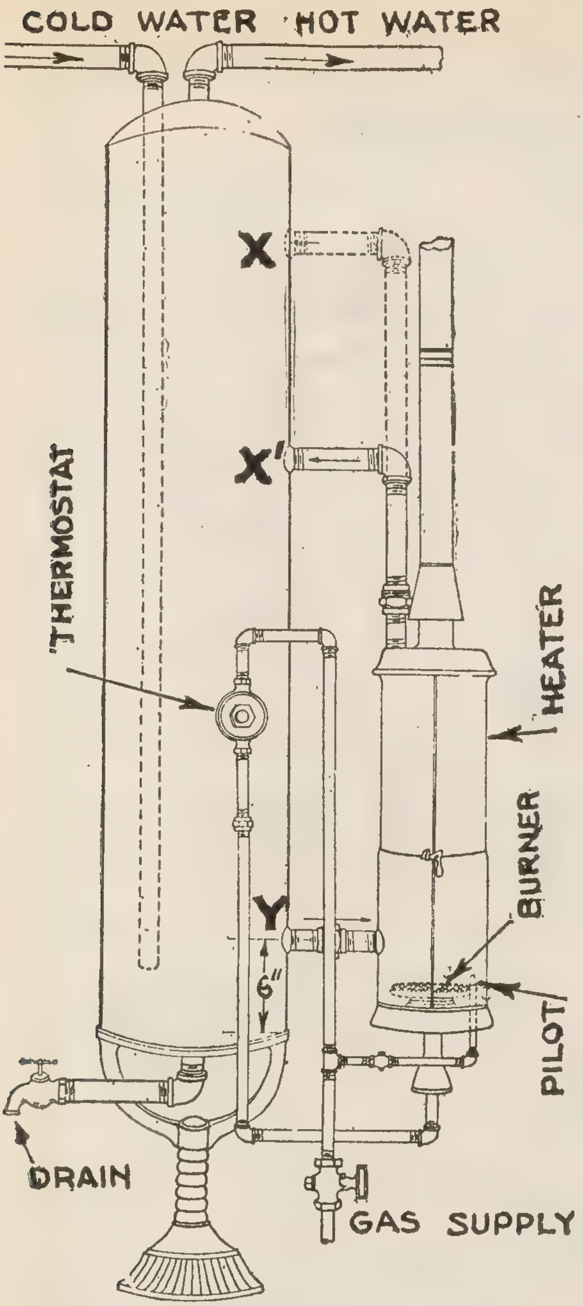
If a storage system be not equipped with a pressure relief valve and there be a check valve between the tank and the street service, then at least one faucet should be of the pressure relief type.

Assembled Systems.—There is very little chance of making any mistake in connecting up these systems as there are only three pipe connections to be made, namely, cold water inlet, hot water outlet and gas. Of these, there could only be a question as to which was the correct cold water or hot water connection as they are both usually located at the top of the vertical storage tank.

Most manufacturers label the connections, but should they not be discernible, they can be distinguished by the fact that the cold water connection has an internal tube reaching to a point near the bottom of the tank while the hot water outlet comes directly off the top of the tank.



FIGS. 9,084 and 9,085.—Methods of connecting outside heater to a small circulating system both ***with*** and ***without*** a range tank.



The thermostats on these systems are usually set by the manufacturer at the factory and should not under any circumstances be tampered with. Should an adjustment prove necessary, have it made by the manufacturer's representative. A plumber or gas fitter should not touch a valve unless he is sure that he thoroughly understands its mechanism. Care should be taken when a heater of this type is connected to the water back of a coal stove or furnace, that the thermostat will not be ruined by overheating. This is especially true of tanks below 30 gals. capacity equipped with thermostats that use the expansive force directly for closing the gas valve.

Built up Direct Circulating Systems.—The smallest and cheapest form of this system is one using an ordinary vertical kitchen tank and a circulating heater with a thermostat. This assembly is shown in fig. 9,086 and pictures the most favorable piping for storage at desired temperatures.

Fig. 9,086.—Built up direct circulating system made from an ordinary kitchen tank, a circulating heater and a thermostat. ***For quick heating*** with about 30° Fahr. difference between X and Y, connect at X; ***for slow heating*** with about 10° Fahr, difference between X and Y, connect at X′.

The lower X is located on the side of the tank, the more uniform will be the temperature throughout the tank. The nearer A is to Y, the quicker

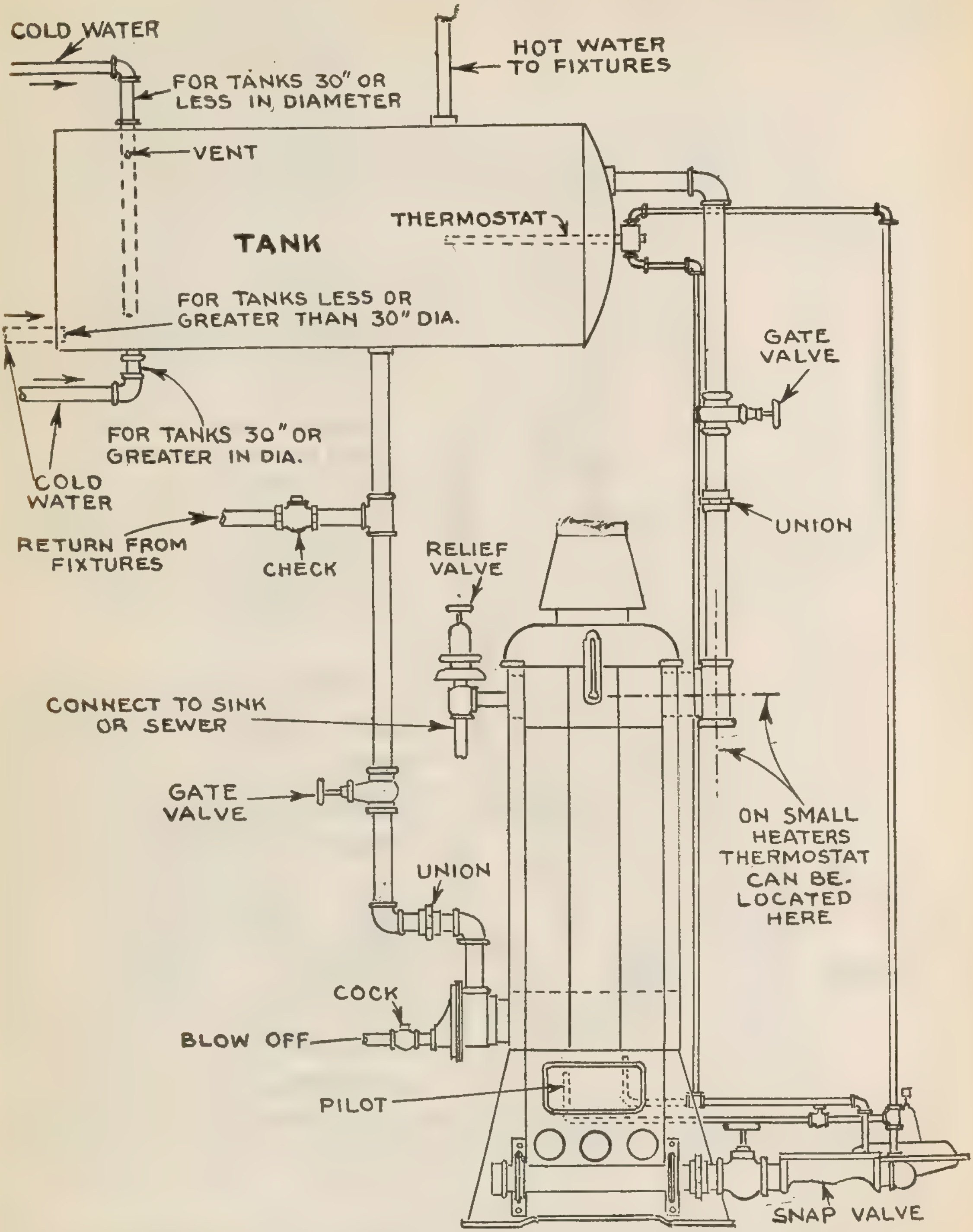


FIG. 9,087.—Gas fired cast iron heater for storage heating.

will the thermostat open and the gas valve on the drawing of any water. It is well to make special mention here of the proper location of the pilot light.

First, it should be so placed that its flame does not interfere with the flames of the main burner.

Second, it should not be placed in front of any opening in the casing where it will be subjected to drafts or rush of air on the ignition or extinguishing of the burners.

Third, the lowest part of the pilot flame should be about 1½ ins. above the burner parts. The use of standard cast iron house heating boilers or of multi-coil heaters for storage water heating has made it possible for gas companies to obtain much larger installations than hitherto. Fig. 9,087 shows a good piping assembly for such a system.

The best location for the thermostat is in the tank at the end where the hot water outlet is located and at half depth of the tank. The heater should be directly under the tank and, in piping, use the largest practical pipe size and only gate valves on the circulating lines.

In the case of the built up storage systems the thermostat comes as a separate part and is not set for any definite temperature.

The following rules can be used as a guide to determine the first "guess" on what will give satisfactory service:

			Degrees F.
1.	*a.*	Private houses under 4 stories	130°
	b.	For each additional floor	5°
2.	*a.*	Apartment houses under 6 stories	135°
	b.	For each additional floor (180° max.)	5°
3.	*a.*	Office and lofts under 6 stories	125°
	b.	For each additional 2 floors	5°
4.		Hotels	160°—180°
5.		Public baths, gynasiums, etc	125°
6.		For dishwashing machines	160°

The above temperatures can in many cases be reduced and should be, if possible, as the lower the temperature the greater the economy up to the point where sufficient hot water is delivered without causing waste.

Direct circulating heaters should not be used where the water pressure is excessive, as in the case of tall buildings. No set rule should be made, but in general it will be well to consider the indirect steam system when the service pressure exceeds 70 lbs. or where the building is over 8 stories in height.

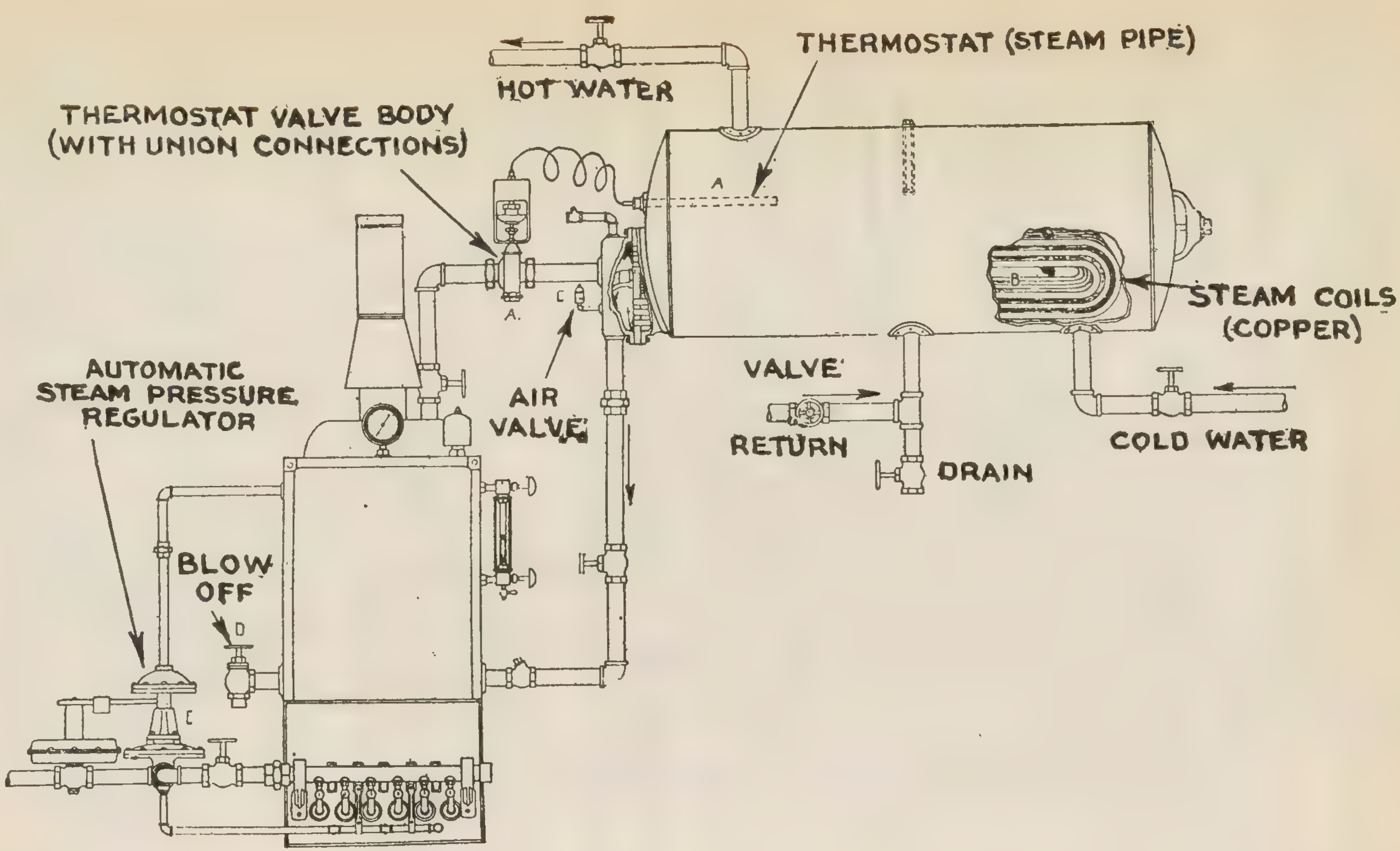


FIG. 9,088.—Direct steam heated hot water storage system. ***The parts are: A,*** thermostat (steam pipe); A′, thermostat valve body (with union connections); B, steam coils (copper); C, air valve; D, blow off; E, automatic steam pressure regulator; F, thermometer. The car type is especially handy when heavy material is to be loaded by a crane, as the car can be filled to capacity outside the furnace and pushed into place. The burners fire into a combustion chamber built in the side wall of the furnace. The products of combustion pass upward over the bridge wall and enter the working chamber. After circulating throughout the heating chamber, they leave through vents located at hearth level, and pass upward through flues in the side walls into the atmosphere.

Built up Indirect Steam Systems.—These consists of a low pressure automatic gas fired steam boiler of the house heating type which supplies steam to coils located in the lower section of a horizontal storage tank or else to a small heater of the instantaneous steam type. The former type of system which is by far the more important is shown in fig. 9,091. The instantaneous type is of little value as it requires too large a boiler unless used in conjunction with a storage tank.

The most important factors to consider in steam heated systems are to get the steam piping and steam coils free of air pockets and to have sufficient head from the steam coil return to the water level of the boiler so that the coil is always well drained. Less than 3 ft. is likely to cause trouble, but in all cases take advantage of all the head room possible.

Fig. 9,091 shows all the necessary parts to this system and the proper location of each. The thermostat shown is of the steam type, but could equally well be one that works directly on the gas supply. If the steam boiler be oversized then the gas valve type is most efficient, but if the boiler be of the correct size then the steam valve has the advantage that it immediately responds, supplying steam to the coils, when the thermostat opens up.

Automatic Instantaneous Heaters.—These heaters differ from all the preceding types in that they do not store up any heated water and must, therefore, heat directly on demand. The points necessary to observe in order to make a good installation are as follows:

1. *Cold Water Supply*. Make sure there is sufficient water pressure to properly operate the water valve. Figure on 10 lbs. per sq. ft. pressure drop through the valve when heater is passing the quantity of water for which it is designed. For example, 6 gals. per min. for a No. 6 size. After allowing for this pressure drop there should still be sufficient water head to assure a good flow from the hot water fixtures on the top floor. A quick way to determine this is to measure the water pressure on the top floor and if it be 10 lbs. or greater, then conditions are favorable. The cold water supply pipe should be of equal size or larger than the inlet connection of the heater. A union should be placed in this line nearest the

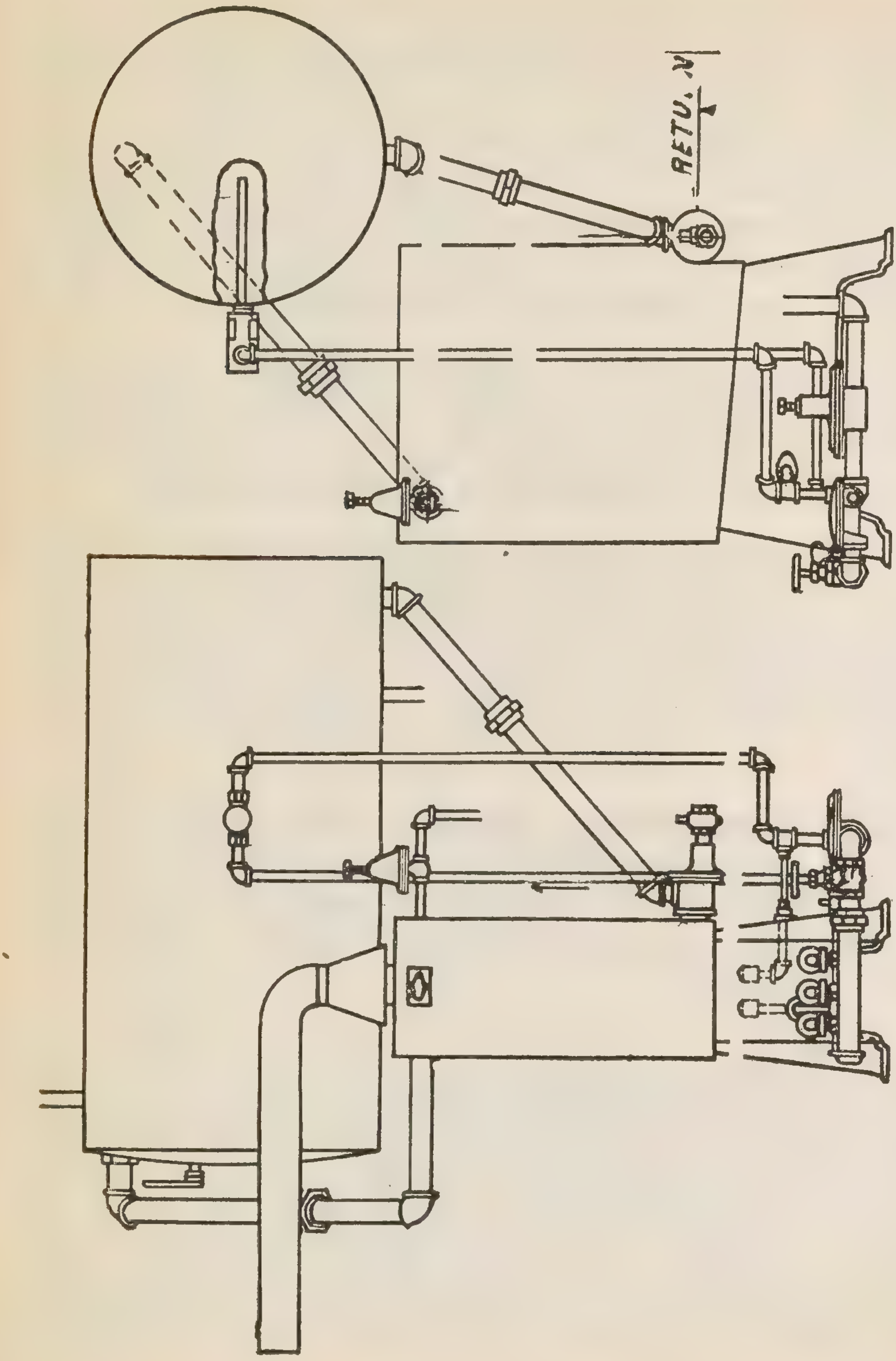


FIG. 9,089 and 9,090.—Bryant automatic hot water storage system. Free circulating type for water pressures not exceeding 70 lbs. per sq. in. ***soft water.***

heater and then a valve for shutting off the supply in the event that repairs are necessary.

2. *Flue Connection.* The next consideration is that a good flue be available. To secure the best results it is absolutely necessary that the heater be connected to a flue which will provide a good draft and that it be further protected with some form of back draft diverter. The flue connection from the heater to the chimney should be as simple as possible and of full size as called for by heater flue collar.

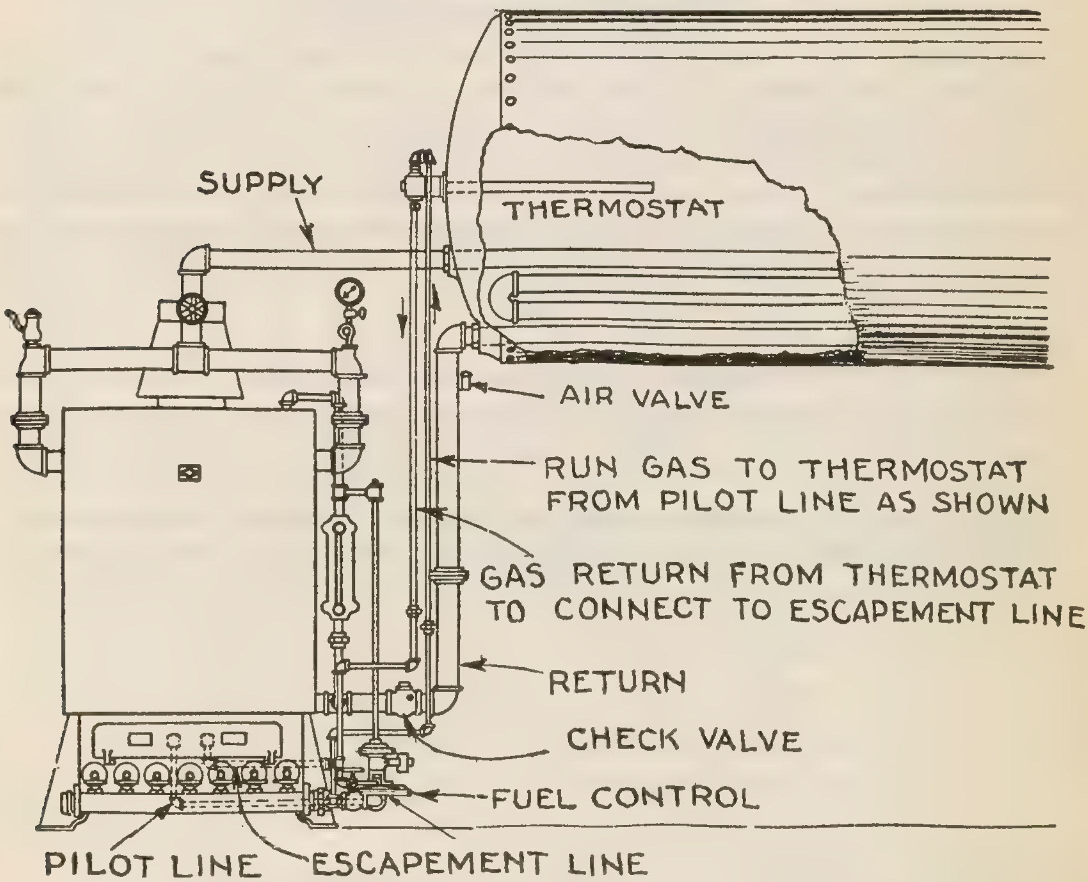


FIG. 9,091.—Bryant automatic indirect storage system for water pressures exceeding 70 lbs. per sq. in. ***hard water.***

3. *Gas Supply.* The gas supply should be of sufficient size to allow for 60 cu. ft. of gas per hour for each gal. per minute rating of heater 600 *B.t.u.* gas. It has always been considered good practice to install a separate supply line for the automatic heaters direct from meter to the appliance. The meter size should be rated on no greater than five-tenths pressure drop. A gas service cock should be placed on the gas supply for throttling purposed in case of necessity.

4. *Hot Water Supply.*—Hot water connection should be made from the outlet of the heater by a line not larger in size than the outlet connection of the heater. A union should be placed on the hot water line near the heater, and beyond this a check valve for the purpose of preventing "re-action" or flashing of the gas when a cold water faucet is closed.

5. *Condensation.*—In some cases where the heater is in continual use, condensation becomes so heavy that it overflows the pan of the heater. This condition may be eliminated by removing the plug in the opening in the pan of the heater and making a permanent drain connection from it.

6. *Location.*—The heater should be placed at a point nearest the fixtures from which hot water will most frequently be drawn, but at the same time it must be placed close to a good flue. It is of greater importance to shorten the flue connection than to provide convenience in the running of gas and water lines; for, if the flue connection be of great length, the hot gases necessary to produce proper draft are cooled in the travel through the long length of pipe and the flow becomes sluggish, frequently choking the flue and connection and causing carbonization of the burners and coils and low heating efficiency.

The location of the heater in relation to the flue being determined, the next point to be considered is to place it as close as possible to the fixture from which hot water will most frequently be drawn. In a residence, this is usually the kitchen. This is done to reduce the length of time elapsing from the time the faucet is opened until the hot water reaches the fixture, and also to reduce the heat loss by radiation which is in direct proportion to the length of the pipe and the number of times the water is drawn.

CHAPTER 139

First Aid

First Aid and Resuscitation in Gas Asphyxiation.—When a man is overcome by gas, the first thing to do is to get him into the fresh air quickly. Fresh air does not mean out of doors in cold weather. Many men have walked from a warm room containing gas to collapse in the cold outside air. Take the patient to a room free from gas and comfortably warm. Be quick, but don't be unnecessarily rough. Remember you are dealing with a human being. If the patient be unconscious, place him on his belly in the position shown in fig. 9,092. If the patient be not breathing or his breathing stop, start artificial respiration at once by the Prone pressure method. Don't wait for apparatus or anything or any one else. Get to work with your own hands. A delay of even a minute may be fatal. If the patient be breathing, wrap him warmly, lay him on his belly, as in fig. 9,092, and give him an inhalation, to be described later.

His breathing may stop. If it do, start artificial respiration again immediately. A man who has been even slightly gassed should not be allowed to make any exertion. Keep him lying down. If he must be moved, carry him. The worst thing that can be done is to get him up and walk him around—as has been done sometimes. It may injure his heart, or even kill him. Keep him on his belly as long as he is unconscious. This may prevent his choking; in this position artificial respiration

can be begun instantly, if necessary; the belly position may also prevent a later pneumonia.

When a gassed patient is breathing, he should not be given artificial respiration. But he should be placed and kept in position ready for artificial respiration, in case he stop breathing. Start inhalation of oxygen+carbon dioxide immediately. If the patient be not breathing, start artificial respiration immediately by the Prone pressure (Schafer) method. This is the best method for artificial respiration. It is better than any

FIG. 9,092.—Position in which patient should always be placed and kept until conscious; also first position for operator starting artificial respiration.

method using a mechanical device. If the victim be breathing, an artificial respiration apparatus may injure him. If he be not breathing, he may die while you are going to get the apparatus or getting ready to use it. It is the opinion of the Commission that such apparatus has led to the deaths of more people than it has saved.

In gas poisoning, it is beneficial to give an inhalation of oxygen+carbon dioxide during artificial respiration. If anything can start a man breathing, this will. When the victim starts breathing, stop artificial respiration. It then does no

good and may do him harm. But continue the inhalation of oxygen+carbon dioxide.

The following directions on how to give artificial respiration by the Prone pressure method should be followed even if the patient appear dead. As soon as the patient is clear of the gas, quickly feel with your finger in his mouth and throat and remove any foreign body (tobacco, false teeth, etc.) If the mouth be tight shut, pay no more attention to it until later. Do not stop to loosen the patient's clothing, but immediately begin actual resuscitation. Every moment of delay is serious. Proceed as follows:

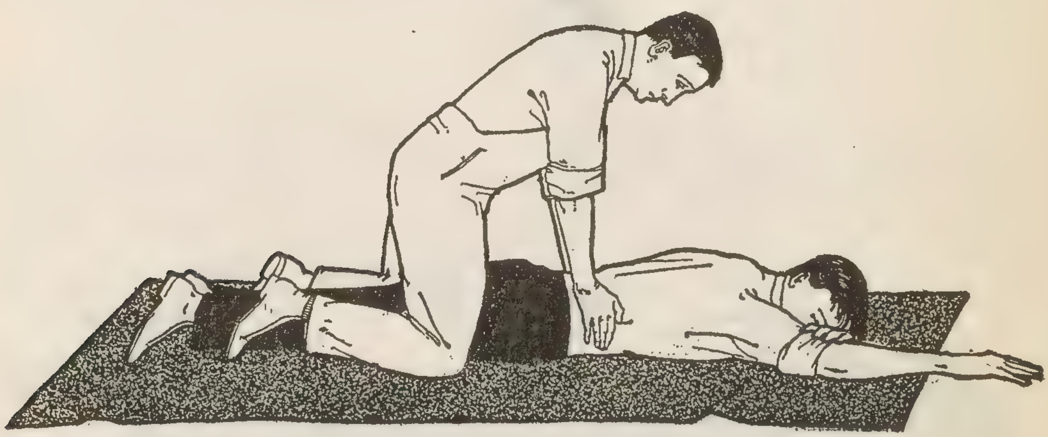


FIG. 9,093.—Second position of operator giving artificial respiration.

1. Lay the patient on his belly, one arm extended directly overhead, the other bent at elbow and with face to one side, resting on the hand of the forearm, so that the nose and mouth are free for breathing (see fig. 9,092.)

2. Kneel straddling the patient's hips with knees just below the patient's hip bones or opening of pants pockets. Place the palms of your hands on the small of the back with the fingers over the ribs, the little finger just touching the lowest rib, the thumb alongside of the fingers; the tips of the fingers just out of sight, as in fig. 9.092.

3. While counting one, two and with arms held straight, swing forward slowly so that the weight of your body is gradually, but not violently, brought to bear upon the patient, as in fig. 9,093. This act should take from two to three seconds.

4. While counting three, swing backward so as to remove the pressure, thus returning to position shown in fig. 9,092.

5. While counting four, five—rest.

6. Repeat these operations deliberately swinging forward and backward twelve to fifteen times a minute, a complete respiration in four or five seconds. Keep time with your own breathing.

7. As soon as this artificial respiration has been started, and while it is being continued, an assistant should loosen any tight clothing about the patient's neck, chest or waist. Keep the patient warm.

8. Continue artificial respiration without interruption until natural breathing is restored, if necessary, four hours or longer, or until a physician

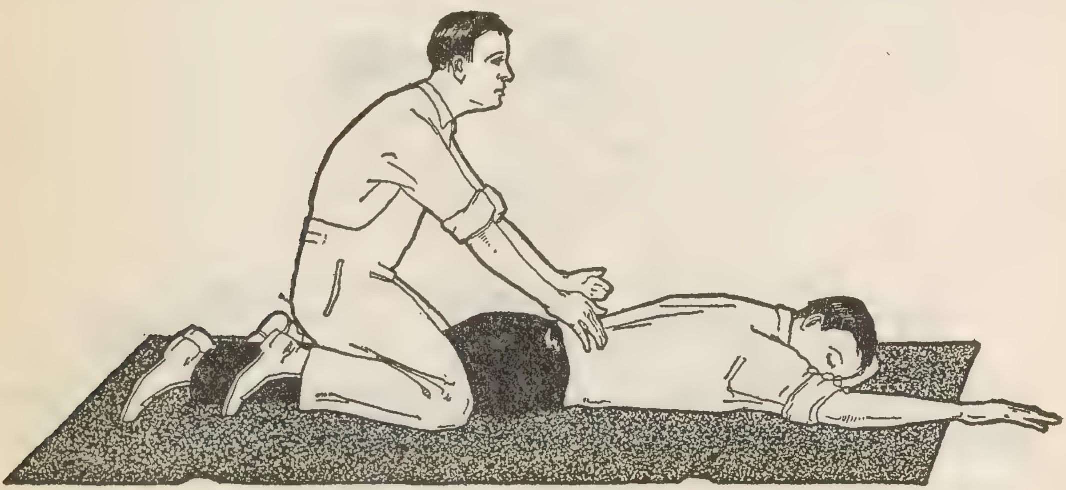


FIG. 9,094.—Third position of operator giving artificial respiration.

declares rigor mortis (stiffening of the body) has set in. If natural breathing stop after being restored, use resuscitation again.

The following directions give proper procedure in taking care of the patient:

1. Keep the patient warm. Every precaution must be taken to prevent a gas patient becoming chilled. To be chilled means a strain on his already weakened vitality. It may kill him or help to cause pneumonia. Wrap him in blankets and use hot water bottles or hot bricks. You can fill a hot water bottle from the radiator of an automobile. Be careful to protect the patient from burns by hot water bottles or bricks against the

bare skin. An unconscious man has no way of telling you when he is being burned. A burn may be worse than the after effects of the gas.

2. Breathing. Remember always: the most important thing is to see that the patient continues to breathe. If he stop breathing, don't wait for blankets or hot water bottles. Start artificial respiration.

3. Treatment. Never give an unconscious man anything to drink. It may choke him. Never give whiskey. Whiskey acts on a man in much the same way as gas. It makes a gassed man worse. Hot black coffee is excellent if the man be conscious enough to drink it. When the patient has become conscious, keep him wrapped up warmly. He must be kept quiet. He may want to get up or struggle. Keep him down. After he is conscious, turn him on his back if that be more comfortable, but keep him lying down for at least six hours. Even a little exertion is bad and a gassed man may collapse if he try to walk.

NOTE.—***The use of inhalation to drive carbon monoxide out of the blood.*** In gas poisoning oxygen used properly helps to drive the carbon monoxide from the blood. To do any considerable good the oxygen must be given during the first two hours after the man is out of the gas, the sooner the better. Sometimes the patients do not breathe well after they are brought out of the gas. In fact some stop breathing entirely. Even those who breathe normally often can not get the gas out of their blood fast enough to prevent their being very sick or even dying afterwards. Pure oxygen does not stimulate the breathing. For this reason it is recommended that about 5 per cent of carbon dioxide, which is the gas that is in soda water, be mixed with the oxygen. This makes the patient breathe much more deeply and thus allows the oxygen to drive the carbon monoxide out of the blood very rapidly. The carbon dioxide also keeps the breathing from stopping. It starts breathing more quickly in those on whom it may be necessary to do artificial respiration. It is useless to try to give an inhalation with a tank and funnel or any such makeshift. A properly designed inhaler and close fitting mask must be used.

NOTE.—***General directions for giving the inhalation treatment.*** Start using the inhaler as soon as you can after the patient is out of gas. If the patient has stopped breathing, start artificial respiration immediately and have an assistant apply the inhalation apparatus. In using the apparatus, open the valve at the top of the steel bottle while the pointer on the dial is at O. Put the mask over the patient's face. The lowest part should go well down on the chin. Press down firmly over the nose. Try to prevent leaks. As soon as the mask is properly applied, admit the oxygen+carbon dioxide into the bag and to the mask at a rate not exceeding ten liters per minute. If the man breathe less than the amount fed, the bag will stay full. If he breathes more than the amount, the bag will collapse. As inhalation proceeds, adjust the valve so that the bag does not quite collapse at each breath, but do not give any more than just all the patient takes from the bag, for the gas in the tank will be rapidly exhausted if wasted. Continue the inhalation for twenty to thirty minutes or even forty minutes. depending upon the severity of the case and until the patient is conscious and can answer questions. In using the inhalation treatment, the patient must be kept in the position shown in fig. 9,092. If metal bottles of oxygen+carbon dioxide be not available or become exhausted, pure oxygen should be used. Oxygen alone is, however, a substitute and does not fulfil the requirements for which the inhalation treatment has been designed.

4. After effects. After the patient is conscious, it is the work of the doctor to see that he does not develop pneumonia or other after effects of gas poisoning. If you have done your best and followed these instructions carefully, you have done much to prevent these after effects.

CHAPTER 140

Drawing Instruments

By definition the term mechanical drawing means *drawing executed mechanically by aid of drawing instruments as distinguished from that executed by the unguided hand.* Accordingly the first thing to consider is the drawing instruments, and secondly, how to use them.

Drawing Instruments.—A good draughtsman should have good instruments; in fact the best are none too good and are easily rendered unfit for use unless they be properly handled.

There are two general classes of drawing instruments, those of circular cross section friction joints of Riefler pattern, and those of angular cross section with set screw joints.

The author very strongly recommends the purchase of the circular pattern instruments, as they are superior in every way to the other type.

The following is a list comprising everything needed for general draughting work:

1 drawing board
1 set of instruments
1 tee square
2 triangles, 30° and 45°
1 drawing scale
2 pencils 3H and 6H
1 bottle of drawing ink
1 box of thumb tacks (small)
1 ink and pencil eraser
1 sponge eraser
1 pen holder and lettering pens
1 irregular curve
1 protractor

In some cases involving enlarging or reducing the size of drawings, proportional dividers are necessary.

NOTE.—***The advice*** given by some instructors to beginners to buy a cheap set of instruments for use until he finds out if he be gifted in the art of draughting, is rather questionable, for if an experienced draughtsman cannot do good work with poor instruments, how then can a beginner be expected to accomplish anything, or determine if he have any talent for drawing?

Drawing Board.—The size of the board should be about 2 ins. longer and 2 ins. wider than the size of paper to be used. The board should be made of well seasoned straight grained pine, free from all knots; the grain should run lengthwise of the board.

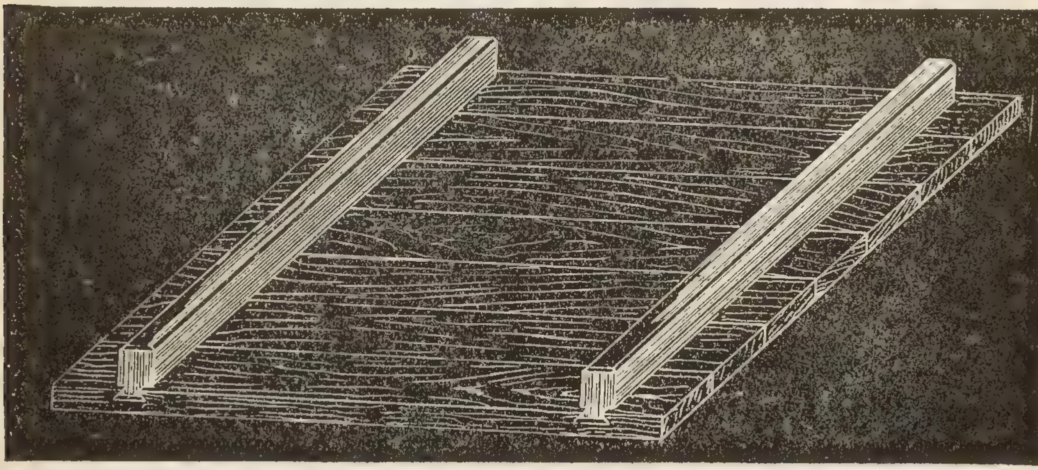


FIG. 9,095.—Ordinary white pine drawing board with dovetailed hardwood cleats or "ledges." This construction permits expansion and contraction. The dovetail grooves are sunk in ¼ the thickness of the board, thus securing a firm grip on the narrow wooden strips. *Standard sizes*: 31 × 43; 37 × 55; 43 × 61; 49 × 73; 49 × 85 ins.

The edges of the board should be square to each other and perfectly smooth in order to provide a good working edge for the head of the tee square to slide against.

A pair of hard wood cleats is screwed or dovetailed to the back of the board. The board should be about three-quarter inch in thickness. The cleats, fitted at the back of the board, at right angles to its longest side, may be about two inches wide and one inch thick. Such cleats will keep the board from warping through changes of temperature and moisture.

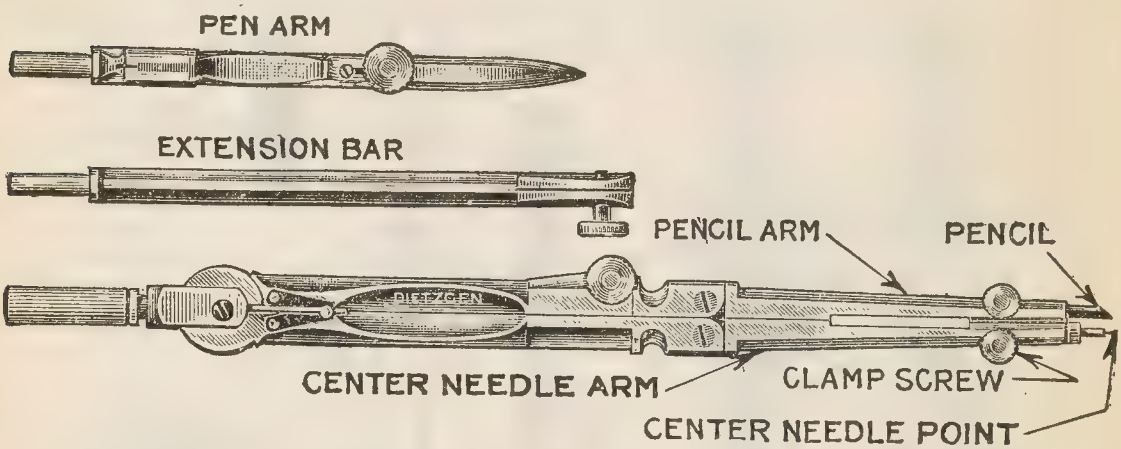
"Set" of Instruments.—Drawing instruments usually come in sets, that is, several instruments in a case. For beginners, and for general use, a set containing the following instruments is all that is necessary.

1 compasses
1 hair spring dividers
3 spring bows (pencil, pen and points)
1 extension bar
1 ruling pen

Compasses.—This instrument is for describing arcs or circles with either pencil or ink. It consists of two legs pivoted together so that they may be set to any desired radius.

One leg carries an adjustable "needle point" or center, and the other has a joint in which may be secured the pencil or pen arms.

Each leg has a pivoted joint permitting adjustment of the ends, so that the end arms which carry the center needle point and pen or pencil may be adjusted perpendicular to the paper for various radii.

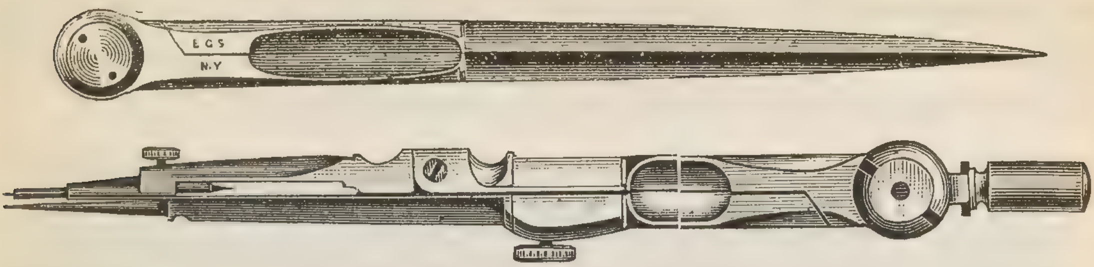


FIGS. 9,096 to 9,098.—Compasses with pencil and pen arms and extension bar. Fig. 9,096, pen arm; fig. 9,097, extension bar, fig. 9,098 compasses with pencil arm clamped to leg.

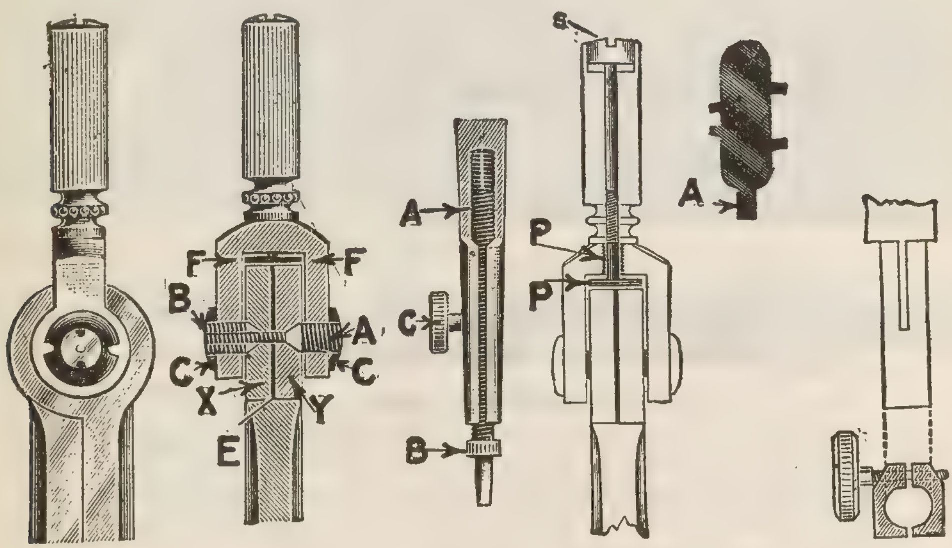
Hair Spring Dividers.—Compasses and dividers are very much alike but each has its special use.

Dividers consist of two legs pivoted at one end and provided with sharp needle points at the other, for use in spacing off distances, as shown in fig. 9,099. For precision, they are fitted with a "hair spring" device, consisting of an adjustable screw controlled by a steel spring in one leg, as shown in fig. 9,100. In operation the legs are set to the approximate desired

NOTE.—***The important requirement*** of good compasses is that the legs may be moved to any radius without any spring back; cheap instruments always spring back making it difficult to set them with precision.



FIGS. 9,099 and 9,100.—Plain and hair spring dividers. Note the sharp pointed legs, and the adjusting screw of the hair spring.



FIGS. 9,101 and 9,102.—Main pivot as constructed for compasses and dividers. FF, arms or pivot forks. The bolt AB, goes entirely through the legs and bolts the forks together. The conical parts of A and B, form the pivot joints which are securely held by lock nuts CC. E, is a steel disc which acts as an anti-friction bearing for the heads of the legs X and Y. To apply tension in adjusting, loosen only one of the lock nuts CC.

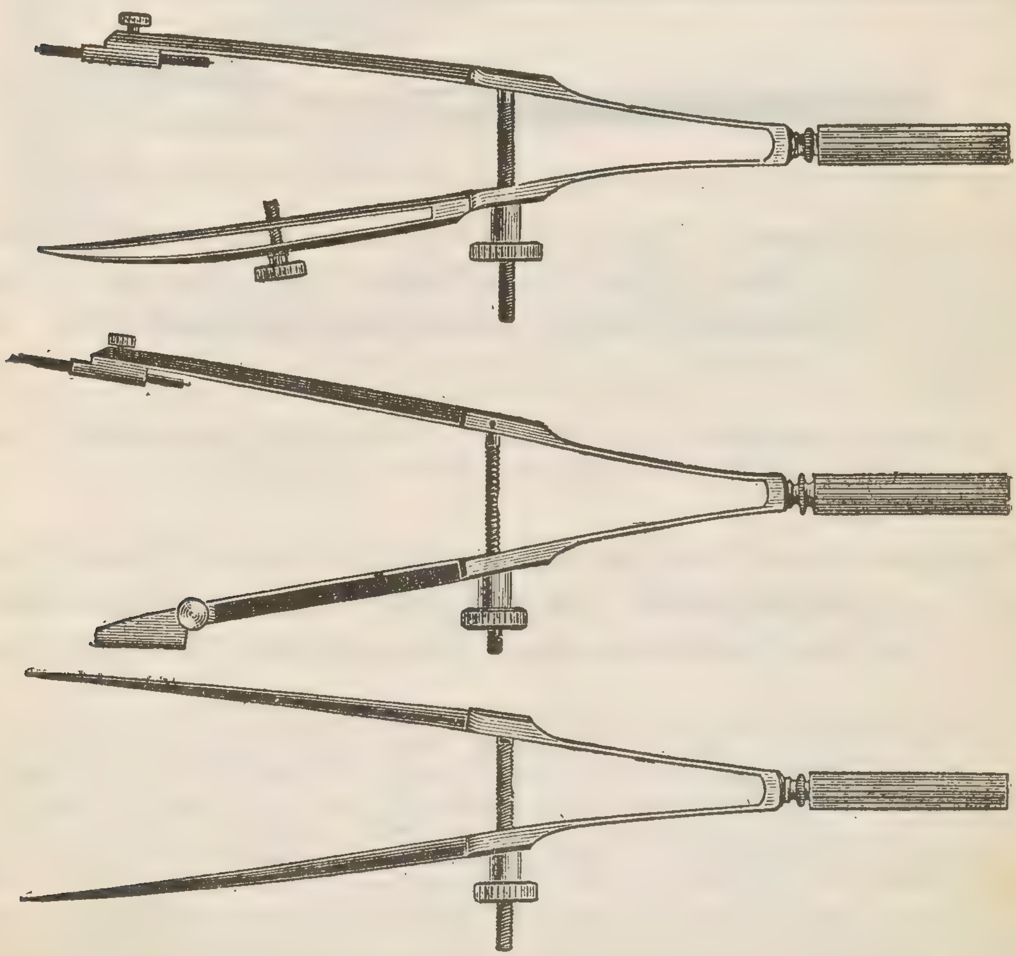
FIG. 9,103.—Screw thread needle point. ***In construction,*** the portion A, is threaded to the extremity of the arm. The portion B, is knurled to be more easily turned with the fingers. The thumb screw C, clamps the needle point rigidly.

FIGS 9,104 and 9,105.—Clamping device. ***In operation,*** by a turn of the key A, the screw S, is pressed down on pin P, which is fastened to the small plate P. The plate P, rests on the top of the legs of the compasses or dividers and when pressed down by turning the screw S, holds the legs firmly in the desired position. The device is useful when spacing or using the same opening of compasses or dividers repeatedly.

FIG. 9,106.—Shank and clamp socket. In the round form, the feathered shanks fit into side clamping spring sockets. By this construction the interchangeable parts of the compasses are firmly locked twice. First, by the steel feather of the shank, and secondly, by the clamping sockets being drawn together with the screw.

position and brought to the exact position by turning the adjusting screw.

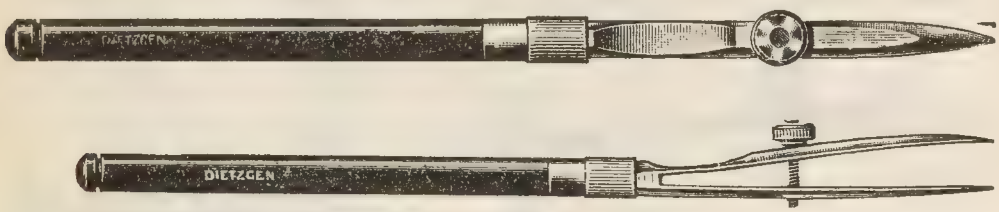
Spring Bows.—These small compasses and dividers made with two spring legs whose distance apart is regulated by a small through bolt and thumb screw. They usually come in sets of three: pen bow, pencil bow and dividers, as shown in figs. 9,107 to 9,109. Fig. 9,108 is the pencil bow shown without the lead. Spring bows are used for describing circles of small diameter, and for minute spacing.



Figs. 9,107 to 9,109.—Spring bows; fig. 9,107, bow pen; fig. 9,108, bow pencil (shown without lead); fig. 9,109, bow dividers.

Extension Bar.—In order to extend the range of compasses, a lengthening or extension bar, as shown in fig. 9,097, is generally provided which greatly increases the diameters of circles which may be described.

Drawing or Ruling Pens.—A special pen is used for drawing lines, as shown in figs. 9,110 and 9,111. The points are made of two steel blades which open and close as required for thickness of lines by a regulating screw.



FIGS. 9,110 and 9,111.—Side views of ordinary ruling pen spring blade, polished ebony handle.

Tee or T Square.—This instrument is used for drawing lines parallel to the lower edge of the board, and consists of two parts, the head and the blade, these being fastened at 90° to each other.

This is the fixed head type of square. The square is sometimes fitted with a movable head. Both types are shown in fig. 9,112.

Triangles.—For drawing other than horizontal lines, "triangles" are generally used. It is inadvisable to buy cheap wooden triangles, as they soon warp out of true; get only the best made

NOTE.—***A good drawing pen*** should be made of properly tempered steel, neither too soft nor hardened to brittleness. The nibs should be accurately set, both of the same length, and both equally firm when in contact with the drawing paper. The points should be so shaped that they are fine enough to admit of absolute control of the contact of the pen in starting and ending lines, but otherwise as broad and rounded as possible, in order to hold a convenient quantity of ink without dropping it. The lower (under) blade should be sufficiently firm to prevent the closing of the blades of the pen, when using the pen against a straight edge. The spring of the pen, which separates the two blades, should be strong enough to hold the upper blade in its position, but not so strong that it would interfere with easy adjustments by the thumb screw. The thread of the thumb screw must be deeply and evenly cut so as not to strip. Figs. 9,110 and 9,111 are side and end views of an ordinary ruling pen.

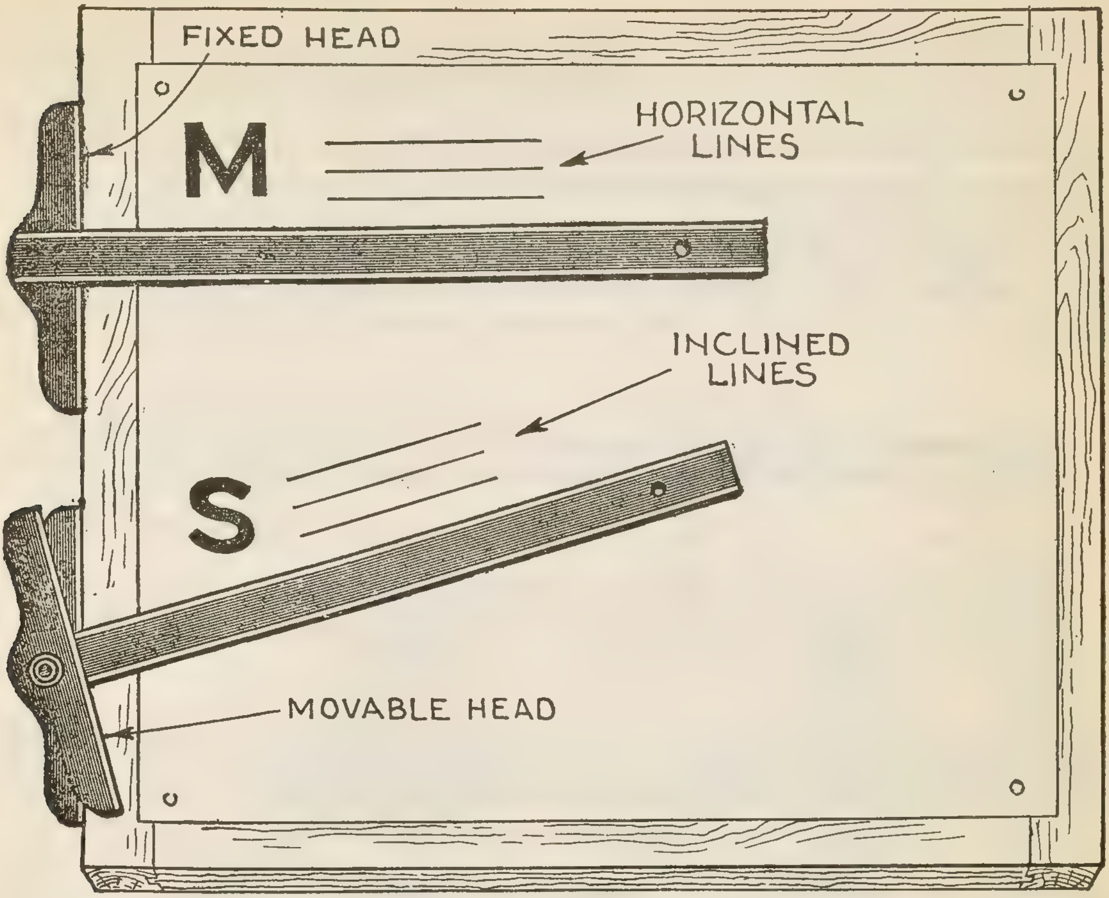
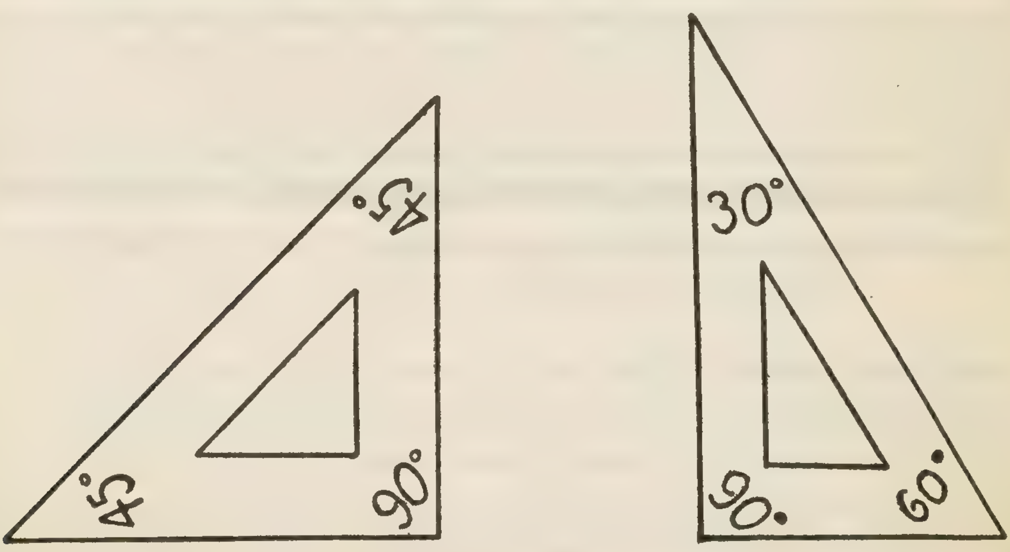


FIG. 9,112.—Fixed and movable head T squares in position on board showing horizontal lines that may be drawn with the fixed head square **M**, and inclined lines with movable head square at **S.**



FIGS. 9,113 and 9,114.—45° and 30° triangles.

of transparent ambro. Two triangles will be ordinarily required —the 45° and the 30°, as shown in figs. 9,113 and 9,114. The first one has two sides at right angles and the third at 45°; the second two sides at right angles and the third making a 30° angle with one side and 60° with the other. By placing these triangles on the T square as in fig. 9,115, vertical, or inclined lines may be drawn.

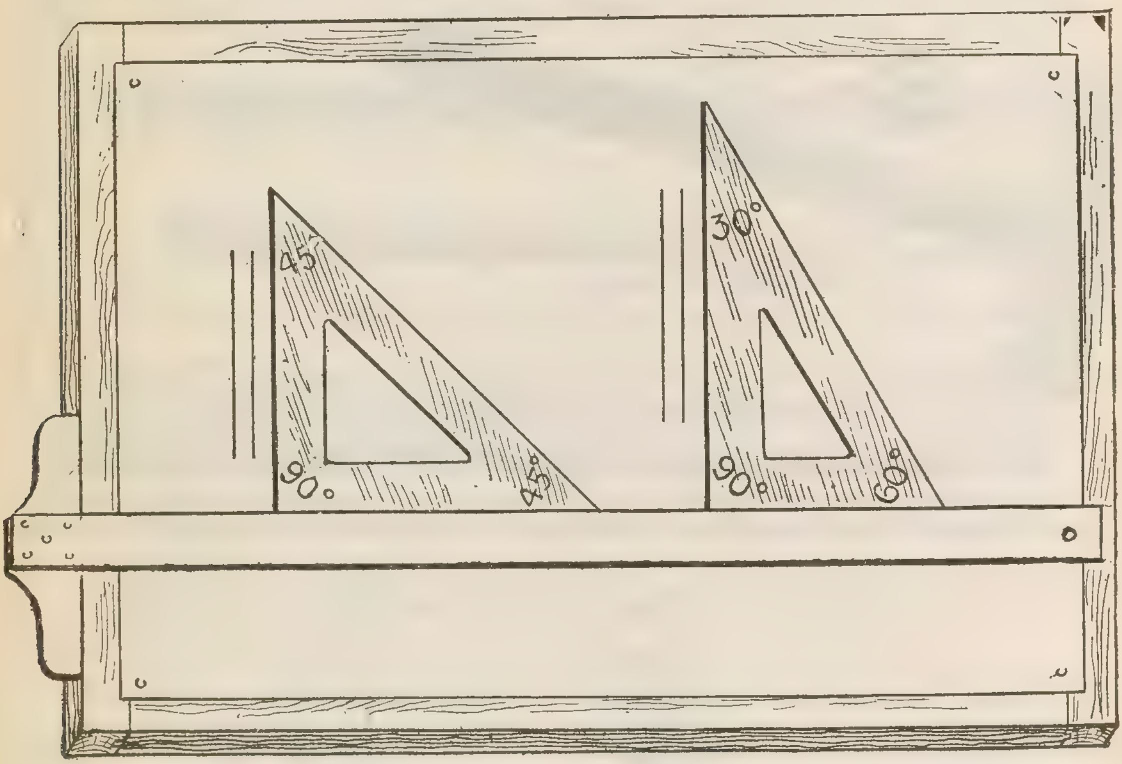
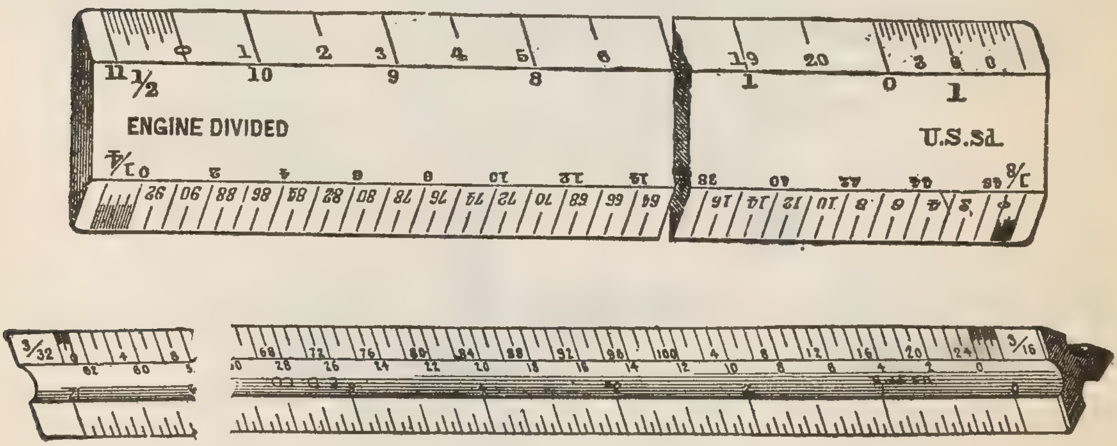


Fig. 9,115.—45° and 30° triangles in position on T square.

Rule and Scales.—The rule is used for measuring and comparing dimensions the same as the ordinary carpenter's 2 ft. folding rule. For the drawing board however it is an instrument of greater precision being usually 10 or 12 ins. long and divided into 32nds. The face is beveled to an edge so that the division

lines will lie very close to the drawing paper, thus permitting distances to be marked off accurately.

When drawings are made the same size as the object that is "full size," a rule of the above description answers the purpose, however, when drawings are to be made smaller or larger than the actual size of the object to be drawn, *scales* are employed. For architectural drawing the various scales are divided into feet and inches with subdivisions. The most convenient forms are the flat or triangular scales as shown in figs. 9,116 and 9,117.



FIGS. 9,116 and 9,117.—Flat and triangular draughtsman's box wood scales. ***An explanation*** of the 1 in. and ½ in. scales will suffice for all. Where it is used as a scale of 1″ to one foot, each large space, as from 0 to 12 or 0 to 1, represents a foot, and is a foot at that scale. There being 12″ in one foot, the twelve long divisions at the left represent inches; each inch is divided into two equal parts, so from 0 to one division at the left of 9 is 9½″ and so on. The 1″ and ½″ scales being at opposite ends of the same edge, it is obvious that one foot on the 1″ scale is equal to two feet on the ½″ scale, and conversely, one foot on the ½″ scale is equal to six inches on the 1″ scale; and 1″ being equal to one foot, the total feet in length of scale will be 12; at ½″ to 1 foot the total feet will be 24.

The triangular scale is the one generally used as it contains six different scales as shown. The usual scales are:

3 ins. = 1 ft.	¾ in. = 1 ft.
1½ ins. = 1 ft.	⅜ in. = 1 ft.
1 in. = 1 ft.	¼ in. = 1 ft.

These scales are usually designated by the length of the foot

division as for instance the 1½ or ¾ in. scale. On each scale, as can be seen, the first foot is divided into inches, and where the scale is large enough, into fractions of an inch.

Drawing Ink.—India ink, and not ordinary ink is used. It can be obtained either in the dry (stick) or liquid form.

Although the dry ink is considered the best, it is not generally used because of the time and skill required in mixing. The liquid India ink comes in small bottles having a quill attached to the cork, by means of which the pen is easily filled. It can be had waterproof.

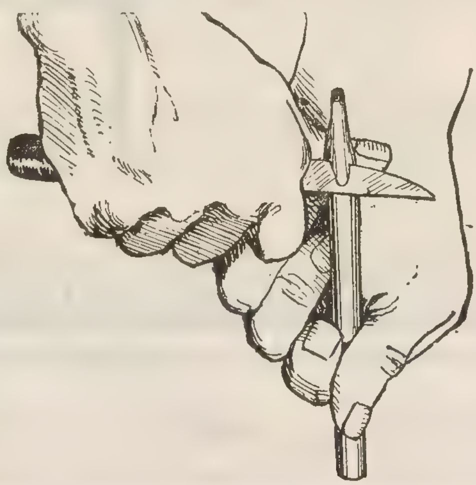


Fig. 9,118.—How to sharpen a pencil. Hold the pencil firmly in the left hand, as in the drawing, allowing about an inch to project beyond the fingers, and turn it gradually as the knife removes the wood. The knife should be held so that the blade alone projects beyond the fingers, and the part of it nearest the handle used for cutting. The pencil should be placed against the inside of the thumb of the right hand, as shown, and the wood removed by slight shaving. The lead should not be cut at the same time as the wood, but rested on the thumb and pared gently afterwards; by attention to these directions the pencil will be economized.

Pencils.—Drawings are generally made "*in pencil*" and then "*inked in*." Pencils are made in various degrees of "hardness," the hardest being designated 9H. The choice as to hardness depends upon the kind of drawing and precision. For ordinary work, as in laying out house frames on a large scale, a 3 or 4H would do. However, in drawing a roof stress diagram on, say, a scale of 1″ = 2,000 lbs., a pencil no softer than 6H should

be used, because a sharp point could not be maintained with a soft pencil, and precision could not be expected with a pencil having "*an acre of lead*" *on its point.*

Pencils are generally sharpened to a conical point, as in fig. 9,119, but some sharpen them so the lead is wedge shape as in figs. 9,120 and 9,121.

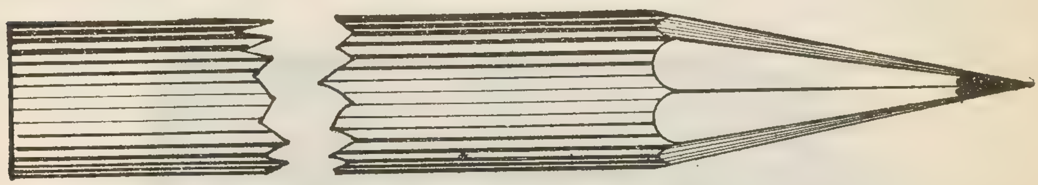


FIG. 9,119.—Pencil with conical point.

FIGS. 9,120 and 9,121.—End and side views of drawing pencil with lead sharpened "wedge shape."

FIGS. 9,122 to 9,124.—Steel stamped thumb tacks. They come in cardboard boxes of 100.

Thumb Tacks.—As stated elsewhere, don't expect to get long service from a drawing board if "spikes" be used for holding down the paper. Thumb tacks are so called because they have a large head so that they may be easily pressed into the board by the thumb. Use the smallest tack that will hold the paper on the board; this will depend somewhat upon the size of the paper, its weight, backing, etc.

Erasers.—There should be three kinds of erasers included in the drawing outfit:

1. Pencil
2. Ink
3. Sponge

For erasing any portion of a line in pencil, a piece of prepared white vulcanized rubber is the best, small in size and of rectangular shape, as in fig. 9,125.

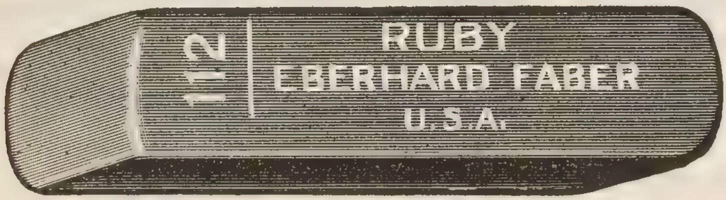


Fig. 9,125.—Ordinary form of pencil eraser.

Fig. 9,126.—Circular form of rubber ink eraser.

An ink eraser is made of a composition of rubber and ground glass, and it should be used as sparingly as possible on drawings, as it roughens the paper and removes the gloss from its surface. Fig. 9,126 shows an ink eraser. Steel ink erasers, as shown in fig. 9,127, are useful in removing defects, overrun lines, joint of lines if swollen, etc.; they have a fine point and can be used to advantage with a little practice; they are used with a scratching, not a cutting, motion.

After a drawing has been made in pencil and inked in it is in a more or less soiled condition. By means of a so called "sponge" rubber as shown in fig. 9,128, which is very soft, pliable and entirely free from grit, the drawing may be cleaned of dirt and projecting pencil lines without disturbing the inked lines or marring the surface of the paper.

Lettering Pens.—Nearly all lettering is executed by a pen similar to a common writing pen, but having a fine or wide point. The width of the point depends upon the desired thickness of the letters. The pen must at all times be kept clean as otherwise no clean cut line can be obtained. Figs. 9,129 to 9,136 show usual styles of pen used for lettering.

FIG. 9,127.—Steel ink eraser.

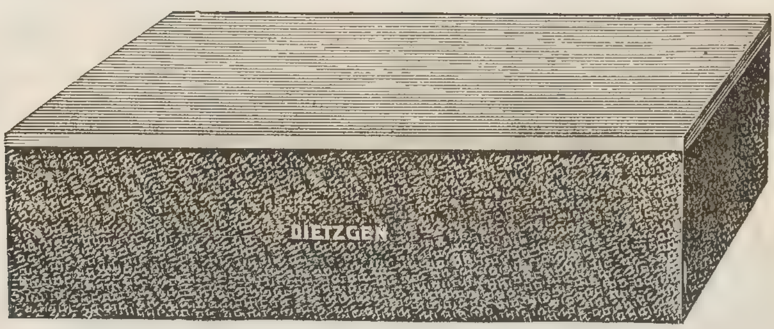
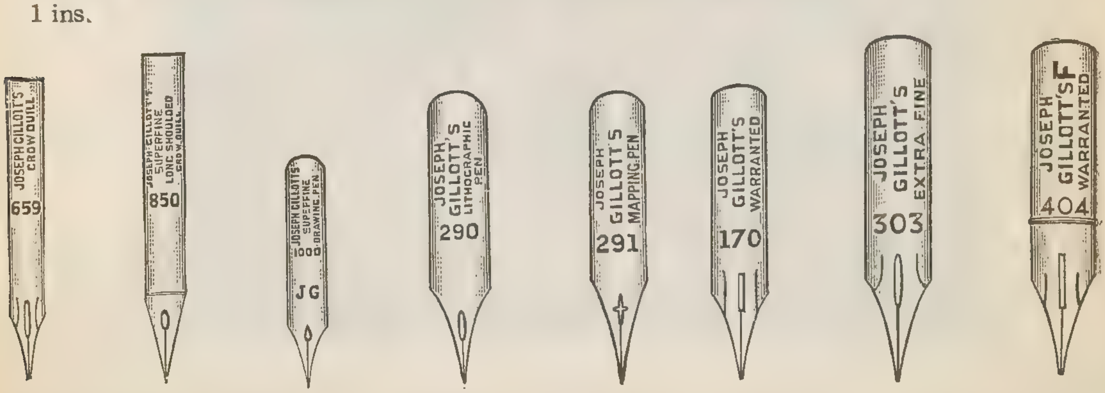


FIG. 9,128.—Sponge rubber, made of soft cellular rubber. Ordinary sizes $1 \times 1 \times 1$ to $4 \times 2 \times 1$ ins.

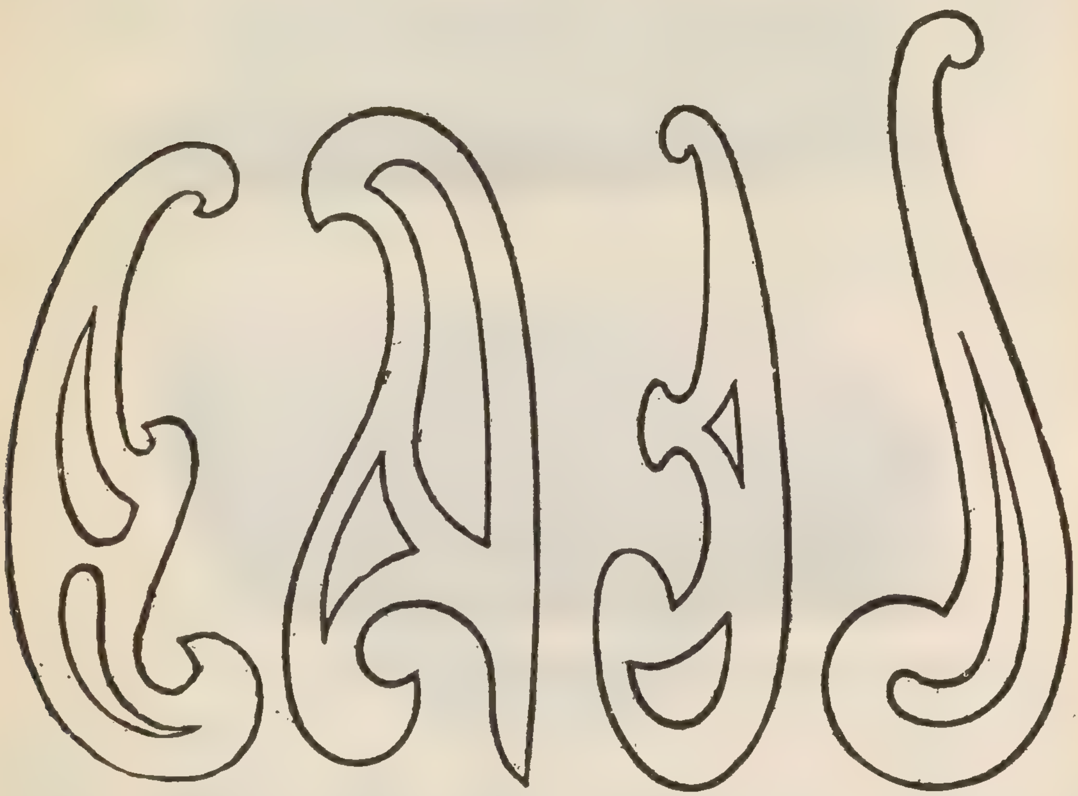


FIGS, 9,129 to 9,136.—Various lettering pens.

Irregular Curves.—For describing curves other than circles, special cut forms called irregular curves are used to guide the pen. These may be obtained in great variety.

A set of two or three will be found frequently useful; several forms of these curves are shown in figs. 9,137 to 9,140.

Protractor.—This instrument is *for laying off or measuring angles*. Fig. 9,144 shows the ordinary form of protractor.



FIGS. 9,137 to 9,140.—Various irregular curves (sometimes called sweeps). They are useful when elliptical or parabolic curves are to be described.

Its outer edge, as shown in the illustration, is a semi-circle with center at **O**, and for convenience is divided into 180 equal parts or degrees from **M** to **S**, and in reverse direction from **L** to **F**.

Protractors are often made of metal in which case the

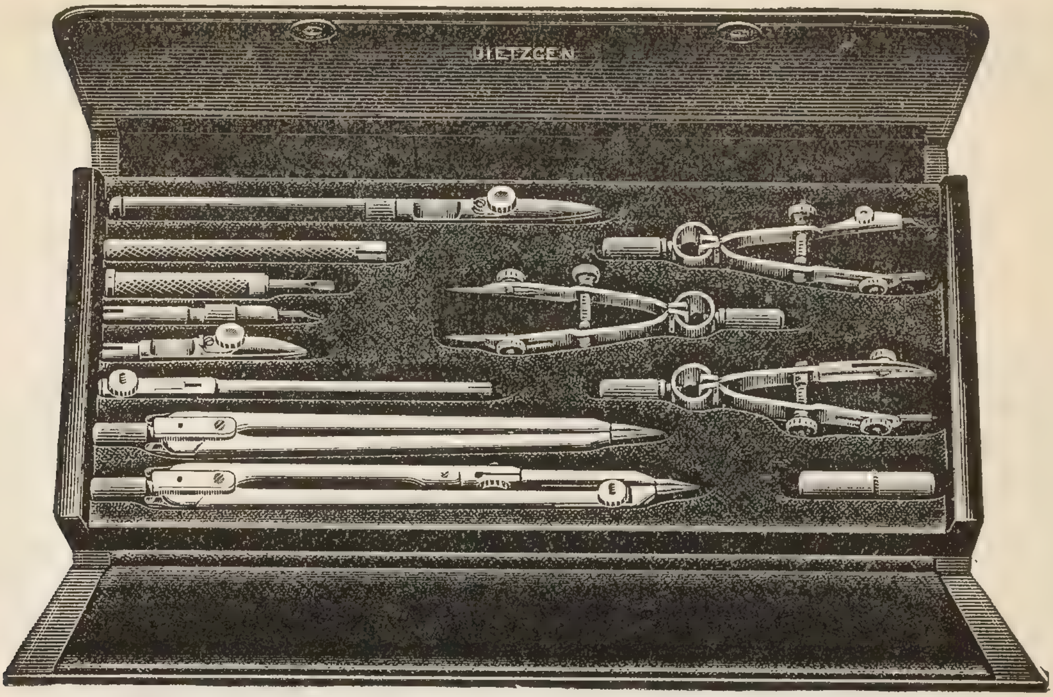


FIG. 9,141.—Dietzgen Riefler pattern or cylindrical set of drawing instruments, ***comprising:*** 5½ in. compasses with detachable needle and pencil points; 5 in. hair spring dividers; 5½ and 4½ in. ruling pens; extension rod; 3 spring bows, pencil, pen, and point; box of leads; key. The extra or small size ruling pen is not necessary but can be used to advantage in some instances.

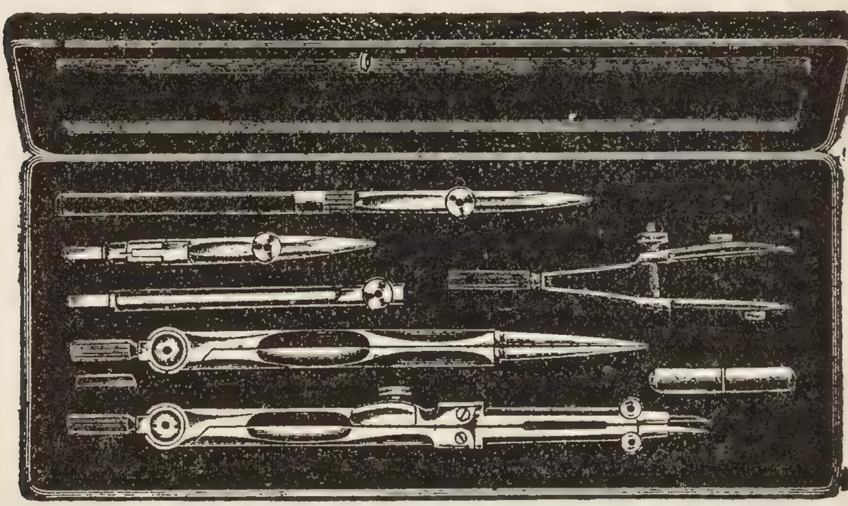


FIG. 9,142.—Set of angular pattern instruments shown to illustrate difference between these and the Riefler pattern or cylindrical instruments recommended by the author. In above figure note the set screws at joints and the shape of the instruments.

central part is cut away to allow the drawing under it to be seen.

A fine precision protractor is shown in fig. 9,219.

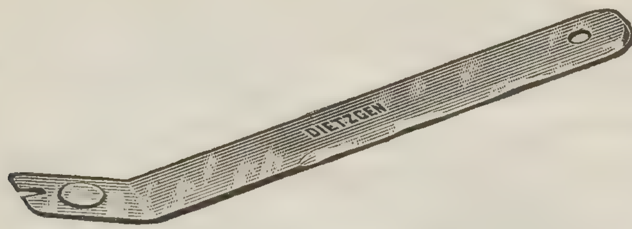


FIG. 9,143.—Tack lifter. Made of metal, nickel-plated. Very convenient for pushing in or for extracting tacks from drawing boards, without injuring the points. The handle can be used as a paper cutter, and is also serviceable for pressing down the edges when stretching paper or for removing sheets which have been gummed to the board.

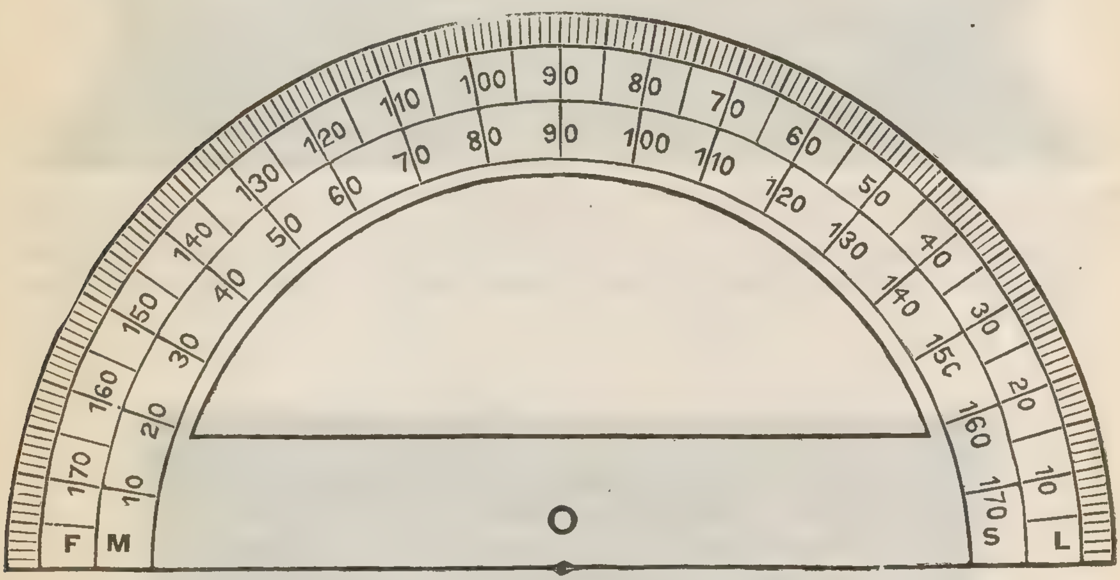


FIG. 9,144.—Protractor for measuring or laying out degrees.

CHAPTER 141

How to Draw

Preparing for Work.—The paper is first secured to the drawing board by means of *thumb tacks*, one at each corner of the sheet. It should be stretched flat and smooth; to obtain this result proceed as follows: press a thumb tack through one of the corners about ½ inch or ¼ inch from the edge. Place the tee square in position as in drawing a horizontal line, and straighten the paper so that its upper edge will be parallel to the

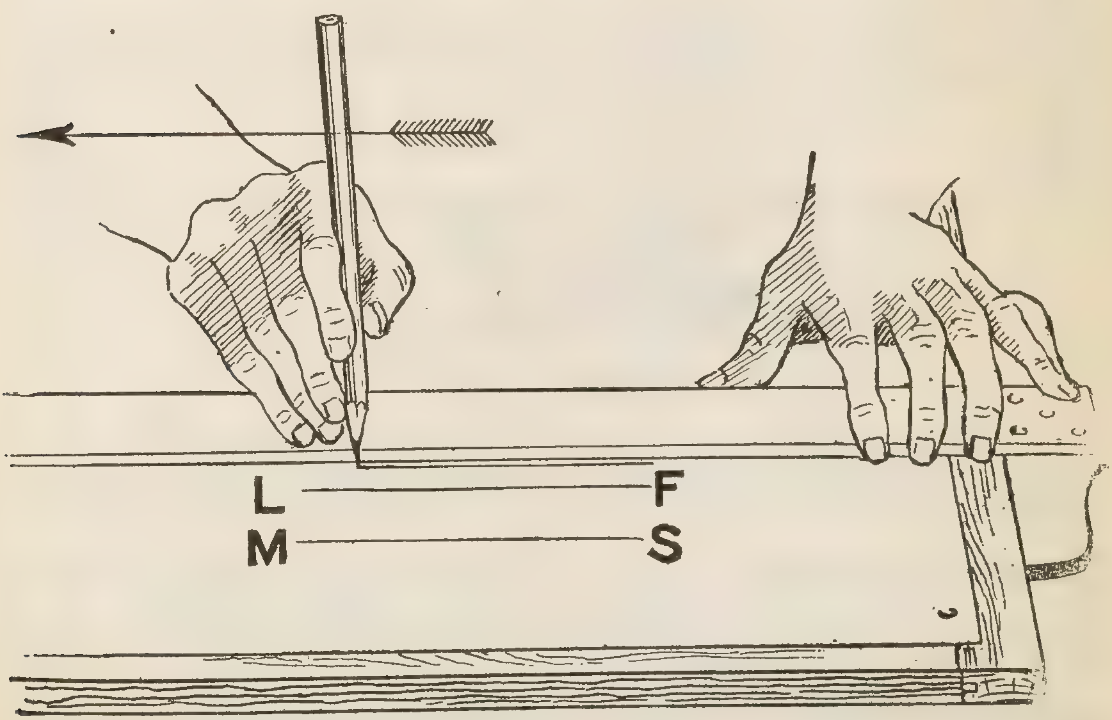


Fig. 9,145.—Parallel horizontal lines. These lines as MS, LF, are drawn by moving the pencil in the direction of the arrow, guided by the edge of the T square.

edge of the tee square blade. Pull the corner diagonally opposite that in which the thumb tack was placed, so as to stretch the paper slightly and push in another thumb tack. Proceed in the same manner with the remaining two corners.

Straight Lines.—To draw a straight line use is made of the

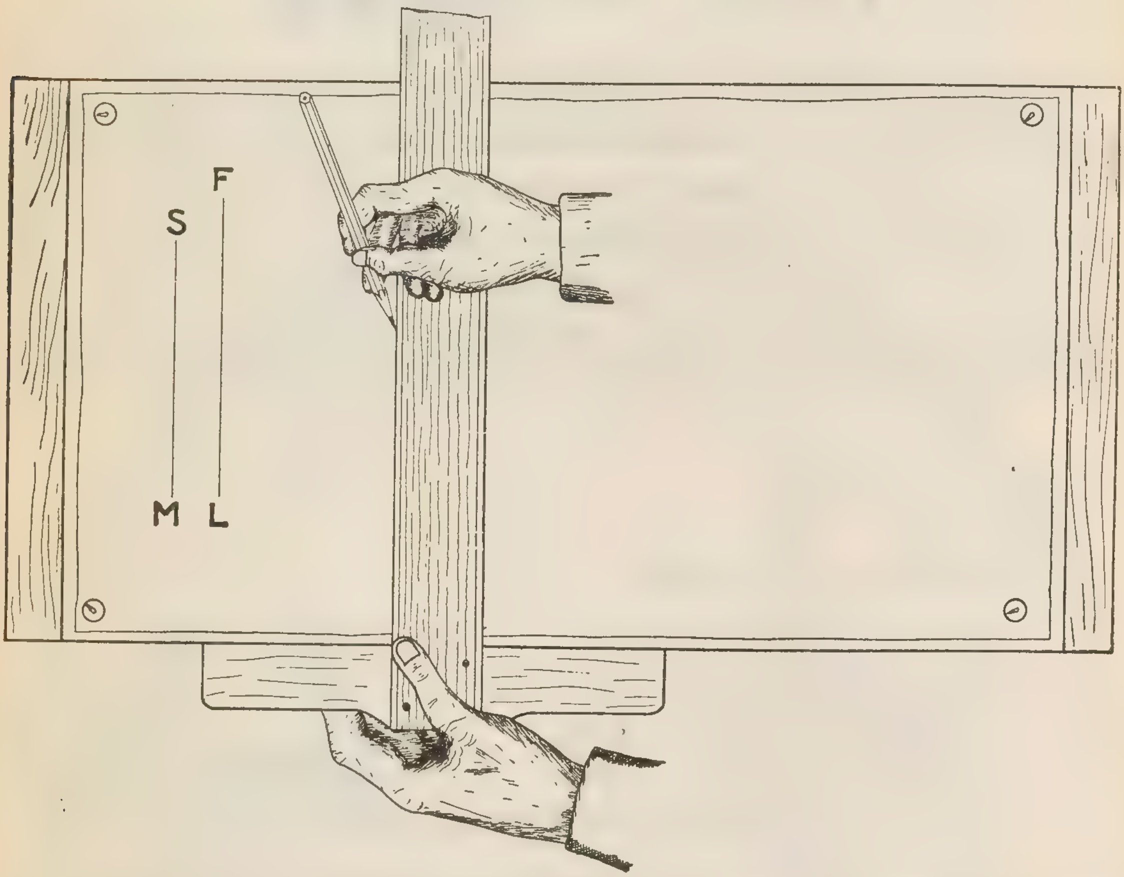


Fig. 9,146.—Parallel vertical lines with T square only. These lines as MS, LF, are drawn similarly as in fig. 9,145, but with the head of the T square in contact with the lower edge of the board.

T square, or triangle, or both, depending upon the direction of the line. Horizontal lines are drawn by aid of the T square as in fig. 9,145 and sometimes vertical lines by applying the head of the square to the lower or horizontal edge of the board, as in fig. 9,146.

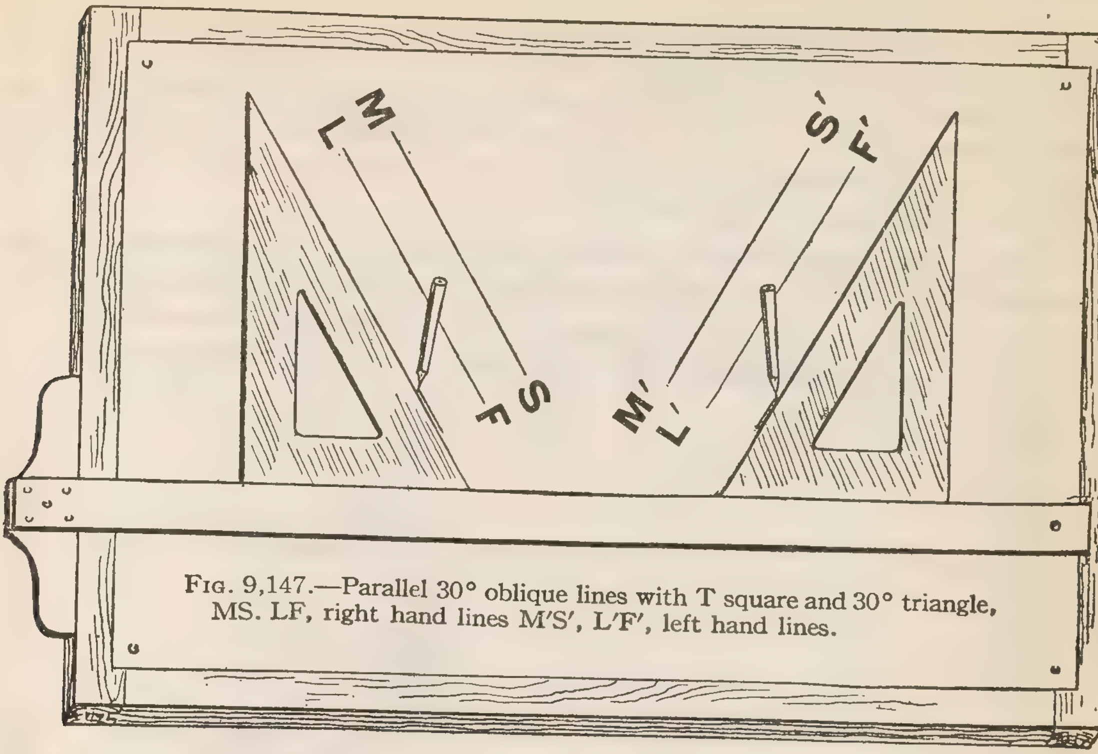


FIG. 9,147.—Parallel 30° oblique lines with T square and 30° triangle, MS. LF, right hand lines M'S', L'F', left hand lines.

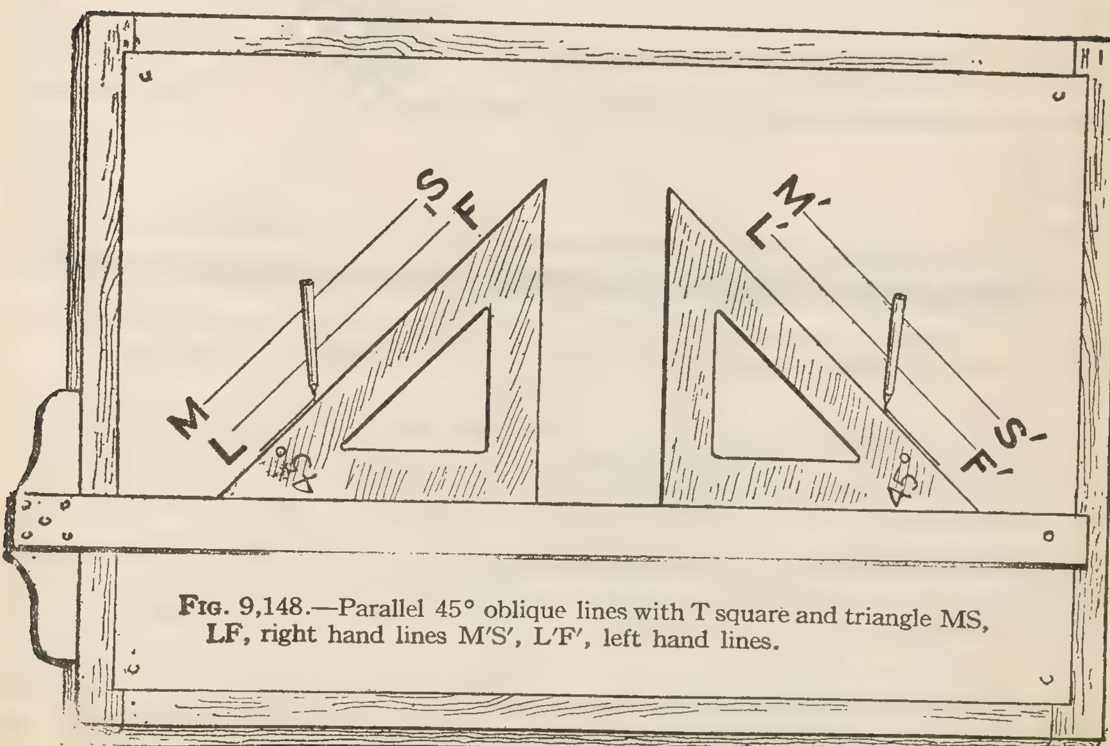


FIG. 9,148.—Parallel 45° oblique lines with T square and triangle MS, LF, right hand lines M'S', L'F', left hand lines.

The usual method of drawing vertical lines is by aid of both the T square and one of the triangles as shown in fig. 9,149. Here one of the "legs" of the triangle is used to guide the pencil. By using the hypotenuse of the 45° triangle, oblique parallel lines may be drawn as in fig. 9,148, and by using the hypotenuse of the 30° triangle, oblique lines may be drawn at 30° or 60° as in fig. 9,147 and 9,150.

By a combination of both triangles as in fig. 9,151, various other angles, such as 15°, 105°, 135°, may be obtained. Sometimes it is desired to draw a

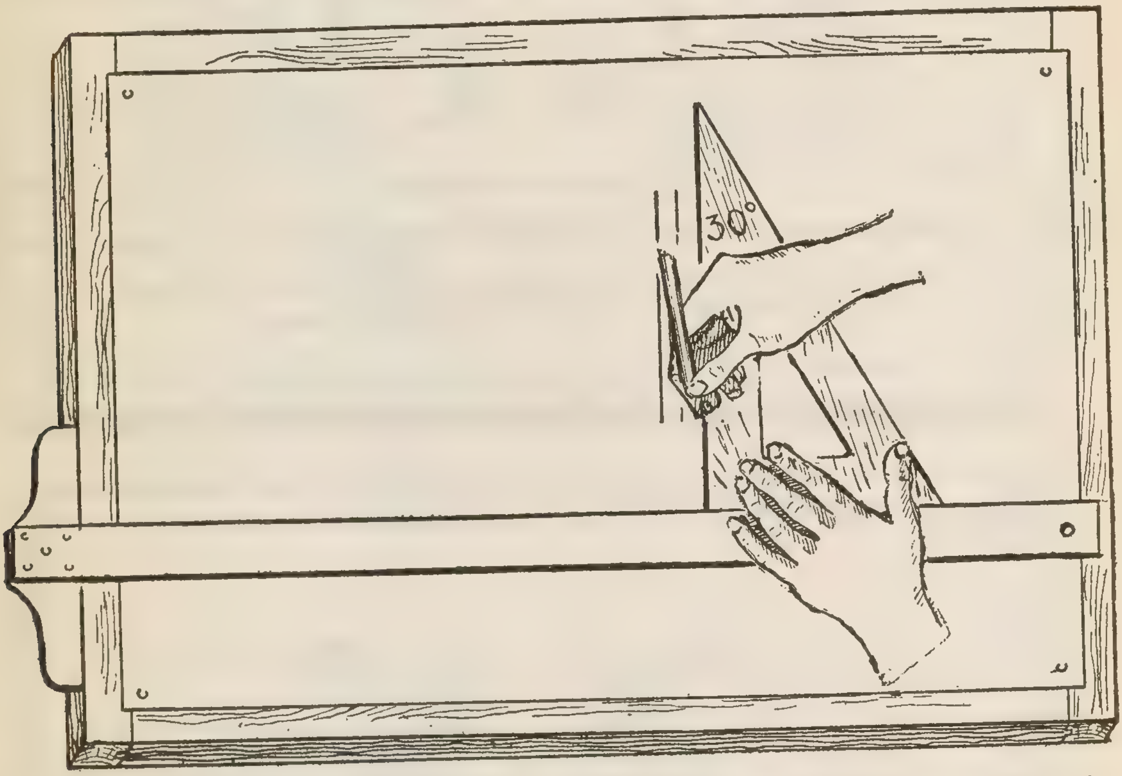


FIG. 9,149.—Parallel vertical lines with T square and triangle. The triangle in contact with the T square is shifted to any position at which it is desired to draw a vertical line.

NOTE.—***The principal paper*** that the pattern cutter has anything to do with is known as brown detail paper, or manila detail paper. It can be bought in almost any width, from 30 ins. up to 54 ins. in rolls of 50 to 100 lbs. each. It is ordinarily sold in the roll by the lb., but can be bought at retail by the yd. although at a higher figure. There are different thicknesses of the same quality. Some dealers indicate them by arbitrary marks, as XX, XXX, XXXX; others by numbers 1, 2, 3; and still others as thin medium and thick. The most desirable paper for the pattern cutter's use is one which combines several good qualities. It should be just as thin as is consistent with strength. A thick paper, like a stiff card, breaks when folded or bent short, and is, therefore, objectionable. The paper should be very strong and tough, as the requirements in use are quite severe. The surface should be even and smooth, yet not so glossy as to be unsuited to the use of hard pencils. It should be hard rather than soft and should be of such a texture as to withstand repeated erasures in the same spot without damage to the surface.

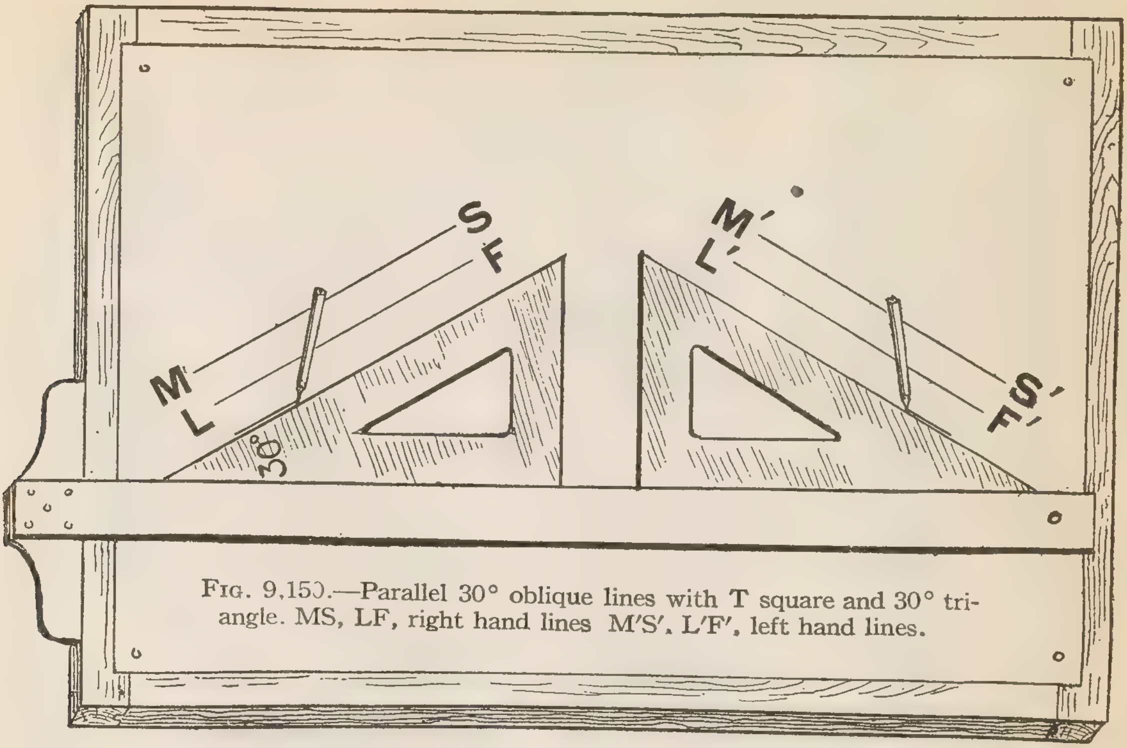


FIG. 9,150.—Parallel 30° oblique lines with T square and 30° triangle. MS, LF, right hand lines M′S′, L′F′, left hand lines.

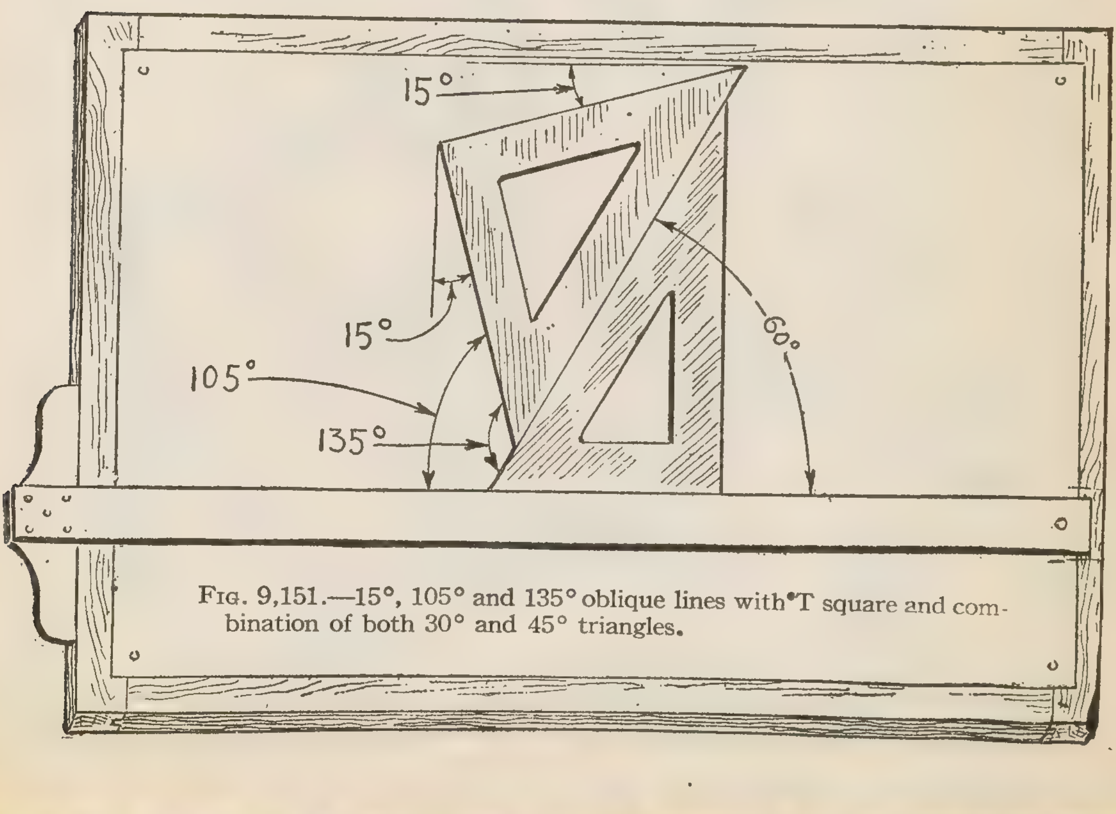


FIG. 9,151.—15°, 105° and 135° oblique lines with T square and combination of both 30° and 45° triangles.

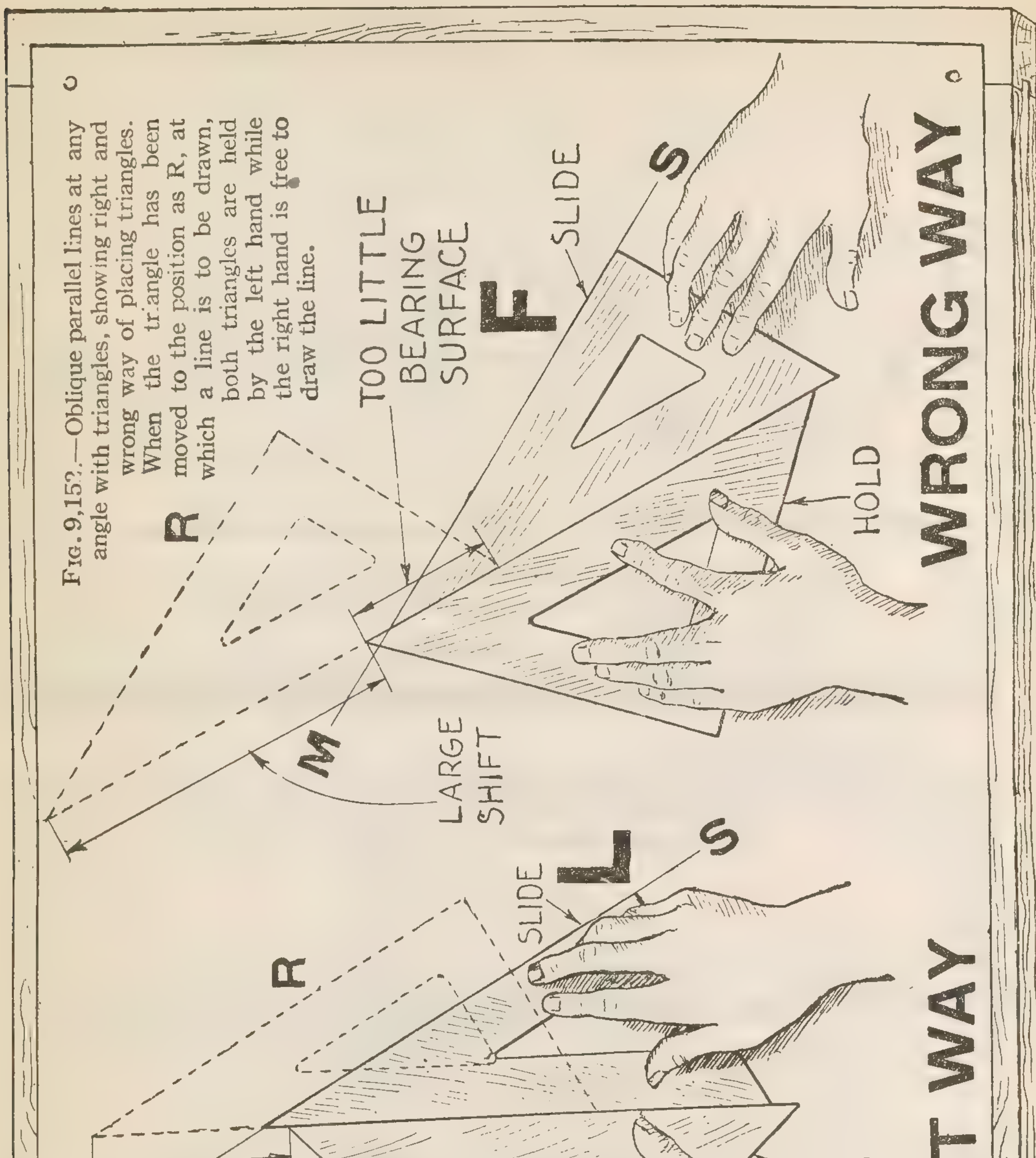
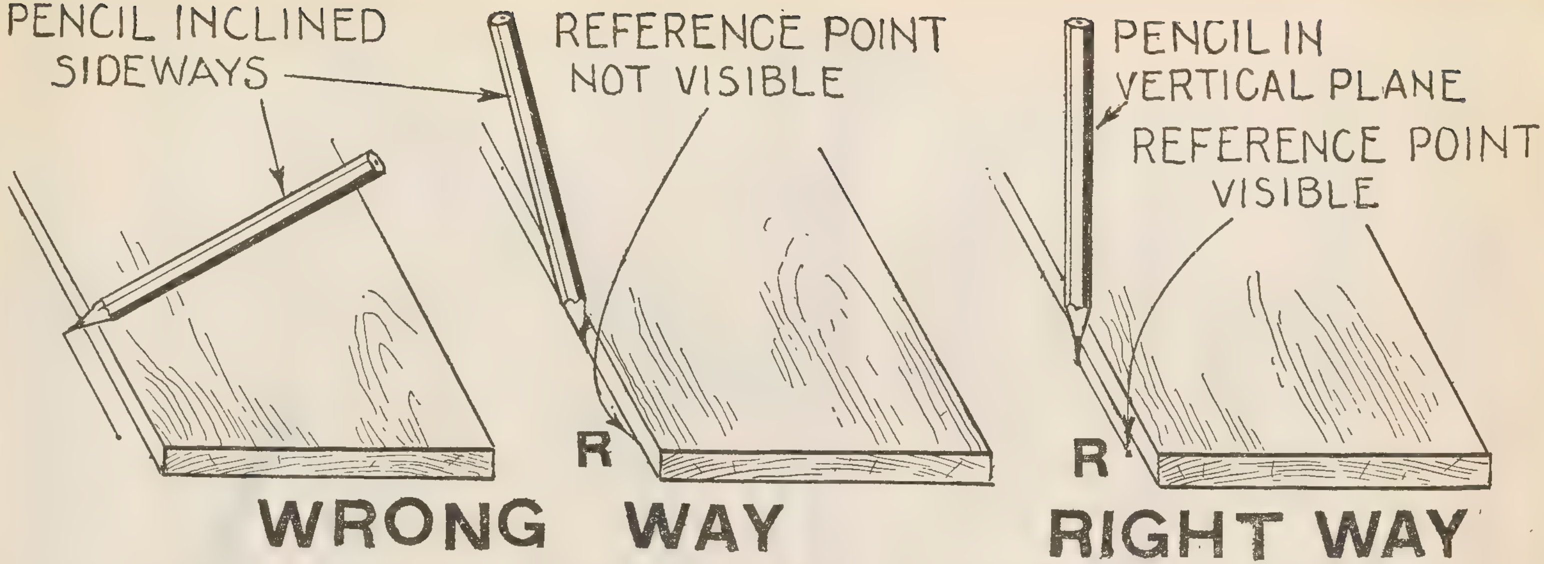


Fig. 9,152.—Oblique parallel lines at any angle with triangles, showing right and wrong way of placing triangles. When the triangle has been moved to the position as R, at which a line is to be drawn, both triangles are held by the left hand while the right hand is free to draw the line.



FIGS. 9,153 to 9,155.—Wrong and right way of using the pencil in drawing lines. It should not be inclined laterally, but in drawing a line (with either pencil or pen) it should be held with its axis in a plane perpendicular to the plane of the paper, slightly inclined in the direction in which it is being moved. If held as in fig. 9,153, the inclination is likely to vary resulting in a wavy line; if held as in fig. 9,154, a reference point R, through which the line is to be drawn, may not be visible or only partially visible. Perpendicular plane, as in fig. 9,155, the line comes very close to the lower edge, the reference point R, can be plainly seen, and there is least chance of drawing a wavy line. In drawing lines with a pencil sharpened to a conical point the pencil should be given a slight twisting motion while the line is being drawn, as this tends to keep the point sharp.

line parallel to another line which is not inclined at any of the angles obtained with the triangles. This is done by placing the edge of one triangle parallel with the given line and sliding it on the other triangle as in fig. 9,152. Note here the right and wrong way to arrange the triangles. Always so place the triangles that the desired point may be reached without too much shifting.

Arcs and Circles.—These are "described" with the compasses. The compasses and the proper position for its use are shown in fig. 9,156. Both points should be

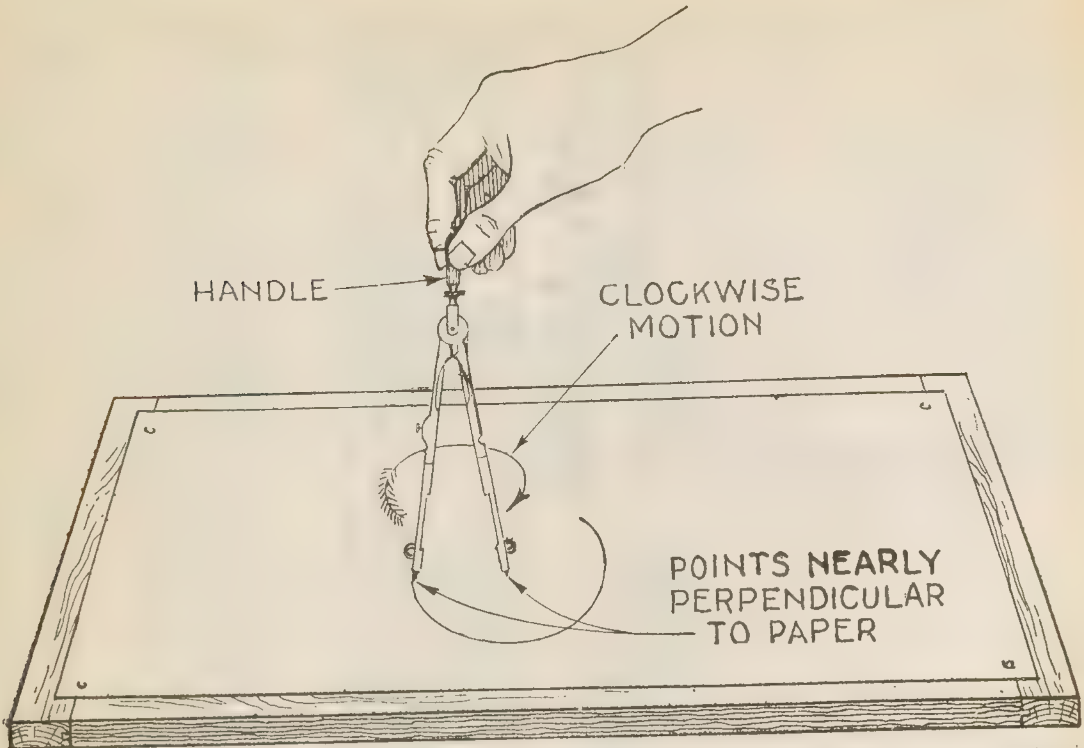
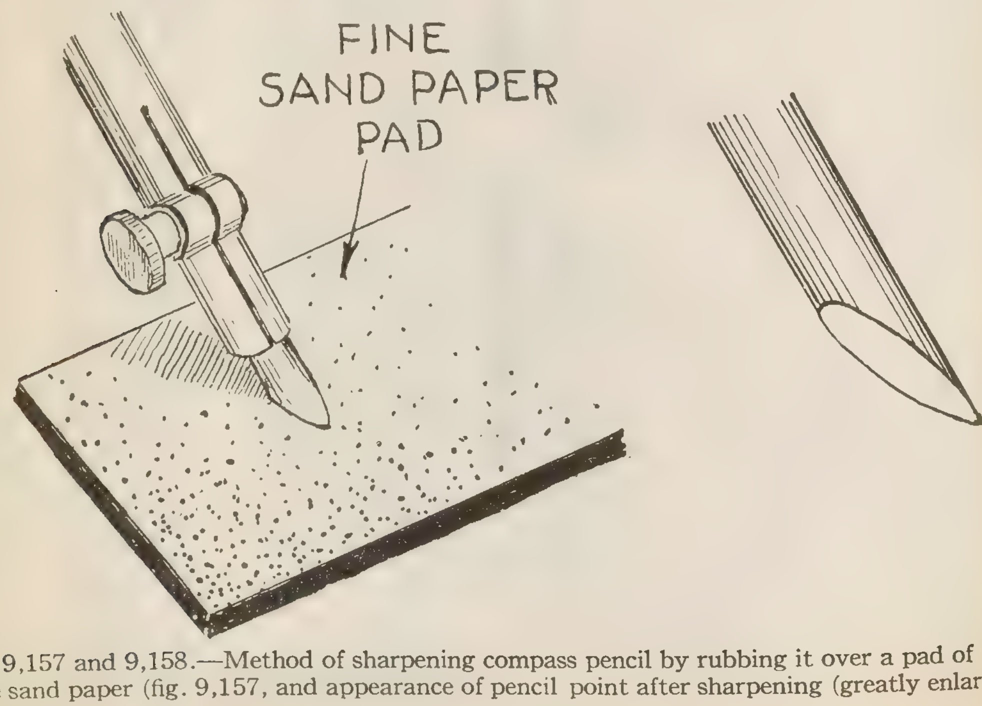


FIG. 9,156.—Correct use of compasses. Note method of holding compasses grasping only the handle; also, upright positions of points, and clockwise motion.



FIGS. 9,157 and 9,158.—Method of sharpening compass pencil by rubbing it over a pad of very fine sand paper (fig. 9,157, and appearance of pencil point after sharpening (greatly enlarged) fig. 9,158.

nearly perpendicular to the paper—slightly inclined in the direction of movement.

The starting position should be such that the entire movement can be made in one continuous sweep by grasping the little handle at the pivot

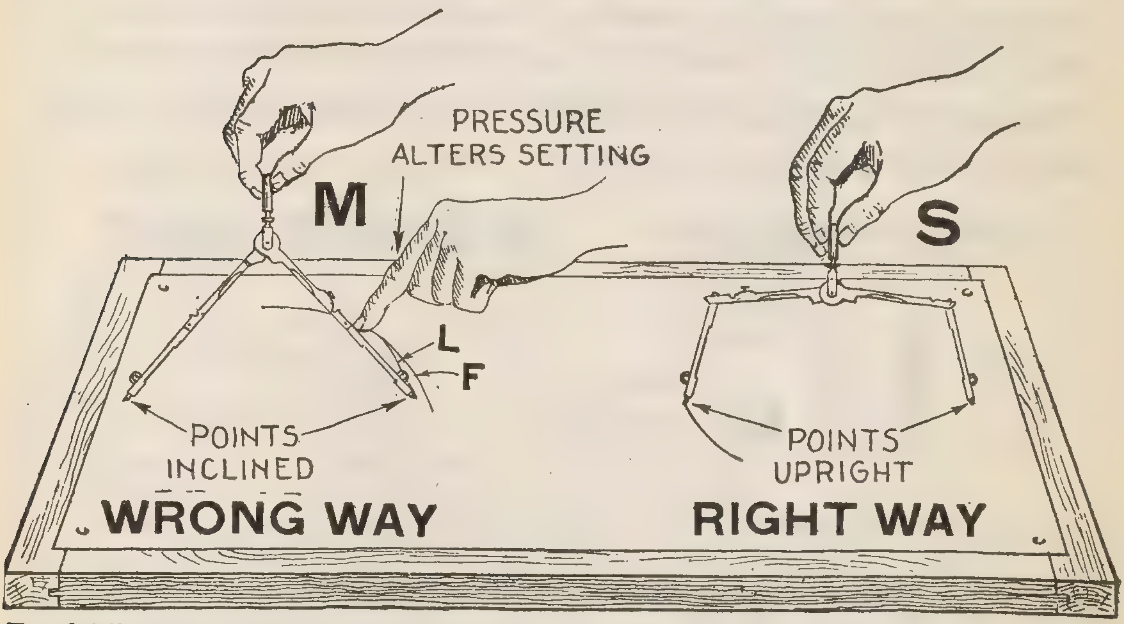


Fig. 9,159.—Wrong and right way to use compasses in describing large circles. Always have the points, especially the center point upright, otherwise the center indentation in paper will be enlarged and untrue. If both hands be used as at M, the setting may be altered by pressure on the leg, and part of the circle, as at L, will vary from the true part F.

NOTE.—***White drawing paper***, which the pattern cutter has occasionally to use in connection with his work, can be had of almost every conceivable grade and in a variety of sizes. The very best quality, and the kinds suited for the finest drawings, come in sheets exclusively although the cheaper kinds are also made in the shape of sheets as well as in rolls. White drawing paper in rolls can be bought in different widths, ranging from 36 to 54 ins. and from a very thin grade up to a very heavy article, and of various surfaces. It is sold by the lb. in rolls ranging from 30 to 40 lbs. each, and also at retail by the yard. A kind known as eggshell is generally preferred by architectural draftsmen.

NOTE.—***Drawing paper in sheets*** is sold by the quire, and at retail by the single sheet. The sizes are generally indicated by names which have been applied to them. The following are some of the terms in common use with the dimensions which they represent placed opposite:—

Cap	13 × 17	Super Royal	19 × 27	Columbier	23 × 35
Demy	15 × 20	Imperial	22 × 30	Double Elephant	27 × 40
Medium	17 × 22	Elephant	23 × 28	Antiquarian	31 × 53
Royal	19 × 24	Atlas	26 × 34	Emperor	48 × 68

end by the thumb and fore finger, obtaining a twisting motion by moving the thumb forward without stopping to shift the hold on the compasses.

For very small circles a smaller compasses called the bow compasses is used; it is more convenient and having screw adjustment can be set with greater precision than the large compasses. Particular attention is called to the result obtained by inclining the center point of a compasses in describing circles as shown at S, fig. 9,160. Since these centers must be again used in inking in a drawing, accurate work cannot be done if the center indentations be spoiled as at S, by wrong use of the compasses.

Spacing.—To accurately divide a given distance into several equal parts hair spring dividers are used. If an exact length is to

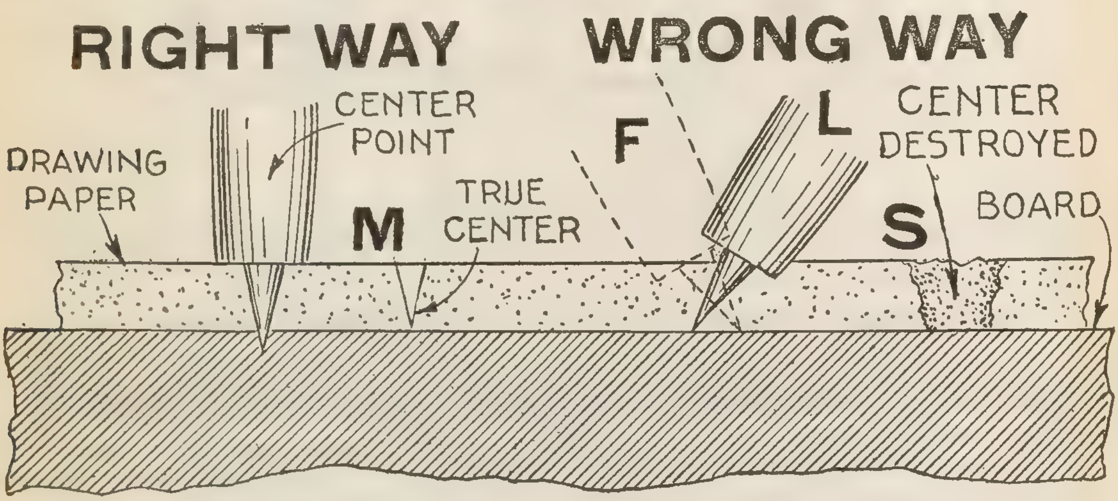


Fig. 9,160.—Right and wrong position of the compasses center point (greatly enlarged for clearness). If the point be perpendicular to the paper in describing a circle as shown at the left, a clean cut indentation will be made in the paper as shown at M, with point removed, being in proper condition to use as a center. Again if the point be inclined in describing a circle the center point will rotate as indicated at L and F, the end of the point enlarging and tearing the indentation so that when the point is removed the indentation will be the condition shown at S, totally unfit to be again used as a center. The center point of compasses should be provided with a shoulder, as shown, instead of being simply conical—this limits the depth of indentation.

be laid off with the dividers, a large multiple of that length should be first laid off with the scale on a right line and then exactly sub-divided into the desired exact length by the dividers.

This involves several trials. Set the dividers as near as can be to the desired length. Then test by spacing with the dividers along the line. The setting of the dividers after each trial is adjusted by turning slightly

the hair spring nut until the correct length is obtained. For very fine divisions the bow dividers are more conveniently used. For precision the divisions L,A,R,F, should be marked off with a "pricker point."

Hints on Pencilling.—The pencil should always be *drawn, not pushed.* Lines are generally drawn from left to right and from the bottom to the top or upwards. Pencil lines should not be any longer than the proposed ink lines. By keeping a drawing in a neat, clean condition when penciling, the use of the

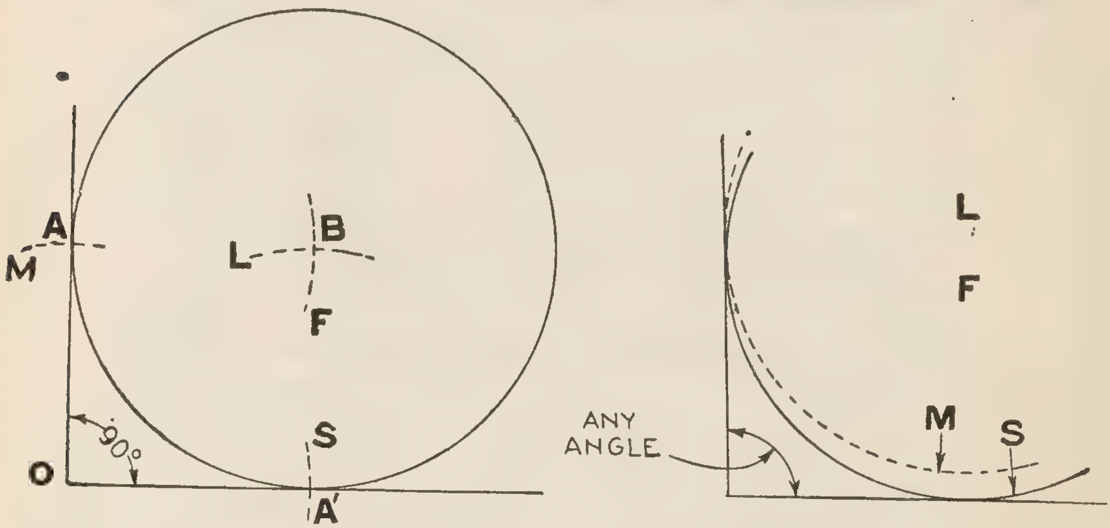


Fig. 9,161 and 9,162.—Two methods of describing a circle of given radius tangent to two lines meeting at a point. In fig. 9,161 let OA, be the given radius. With O, as center, describe arcs M and S. With points A, A′, where these arcs cut the lines describe arcs L, F intersecting at B, then will a circle described with B, as center, and radius OA, be tangent to both lines. ***In the second method,*** set compasses to given radius and describe a trial arc M, from a trial center L, selected with pencil resting on one of the lines. If trial arc be not tangent to the other line, bring compasses back to initial position with pencil point resting on line, lift center point, by inclining compasses a little and select another trial center as F. Continue the process until a center is obtained about which a circle described will be tangent to both lines. With a little practice center can be quickly located by this method. The first method, fig. 9,161, holds when the lines are at 90° to each other, but the second method applies to any inclination.

rubber upon the finished inked drawing will be greatly diminished.

The pencil drawing should look as nearly like the ink drawing as possible. A good draughtsman leaves his work in such a state that any competent person can without difficulty ink in what he has drawn.

Inking.—Always begin at the top of the paper, first inking in all small circles and curves, then the larger circles and curves, next all horizontal lines, commencing again at the top of the drawing and working downward. Then ink in all vertical lines, starting on the left and moving toward the right; finally draw all oblique lines.

Irregular curves, small circles and arcs are inked in first, because it is easier to draw a straight line up to a curve than it is to take a curve up to a straight line.

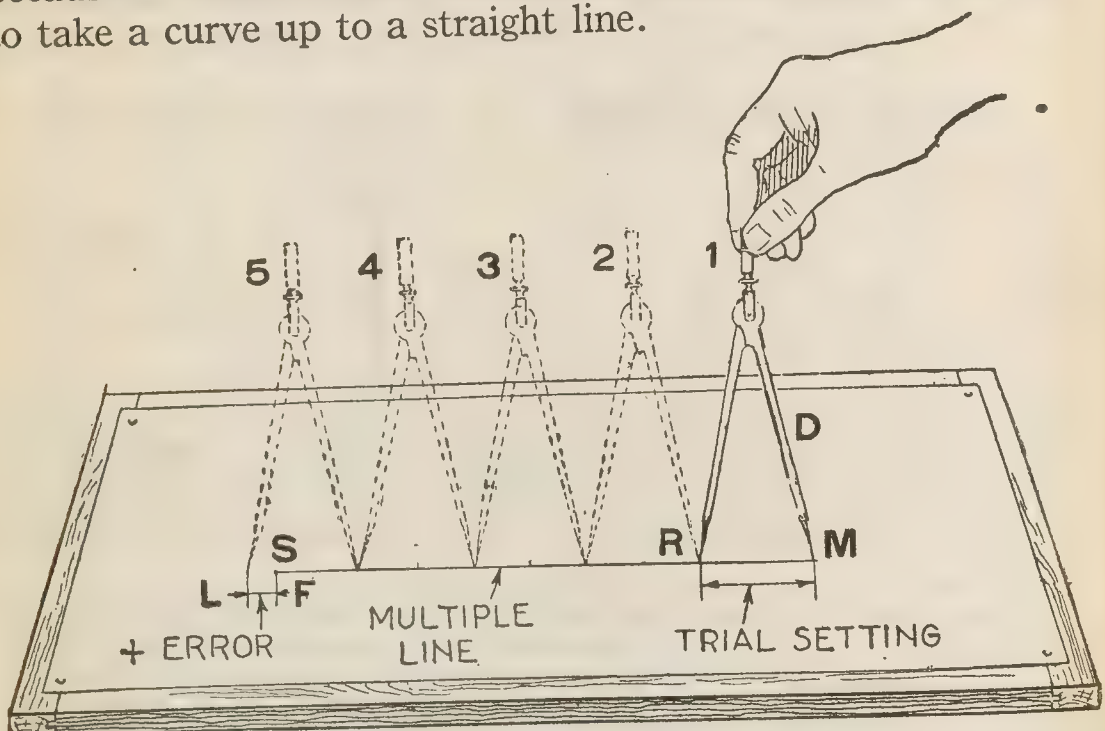


FIG. 9,163.—Spacing with the dividers. Suppose it be desired to divide the line MS, into 5 equal parts. Set dividers "by eye" to one-fifth the distance as MR. Space along the line by moving the dividers clockwise and counterclockwise to position 2, 3, 4, 5. As seen, MR was taken too large. Adjust setting and respace until the correct setting has been obtained. Before setting the dividers "by eye" loosen adjustment nut D, two or three turns, other wise if the error LF, were negative (—), the hair spring could not be adjusted in the positive (+) direction.

In inking in lines the "ruling or lining" pen is used against the edge of the T square and triangles in making ink lines.

The tool has two separate blades, or jaws, one of which is equipped with a spring to spread them apart. It is brought close to the other by a thumb screw or allowed to spread apart by turning the thumb screw. In the better

class of drawing pens a hinge is provided on one blade at the base, thus permitting the blade to open to a right angle, so that it can be cleaned of any ink which may cake or adhere. The ink is inserted between the jaws with a common writing pen or pen cork, which is now provided with every bottle of drafting ink sold, and any ink which remains outside must be cleaned off with a soft rag or piece of soft blotting paper. Similar directions must be followed when using the pen leg and point of compasses.

The drawing pen is applied by holding it perpendicular between the first and second fingers and thumb of the right hand, keeping the smooth blade close against the T square or triangle as required.

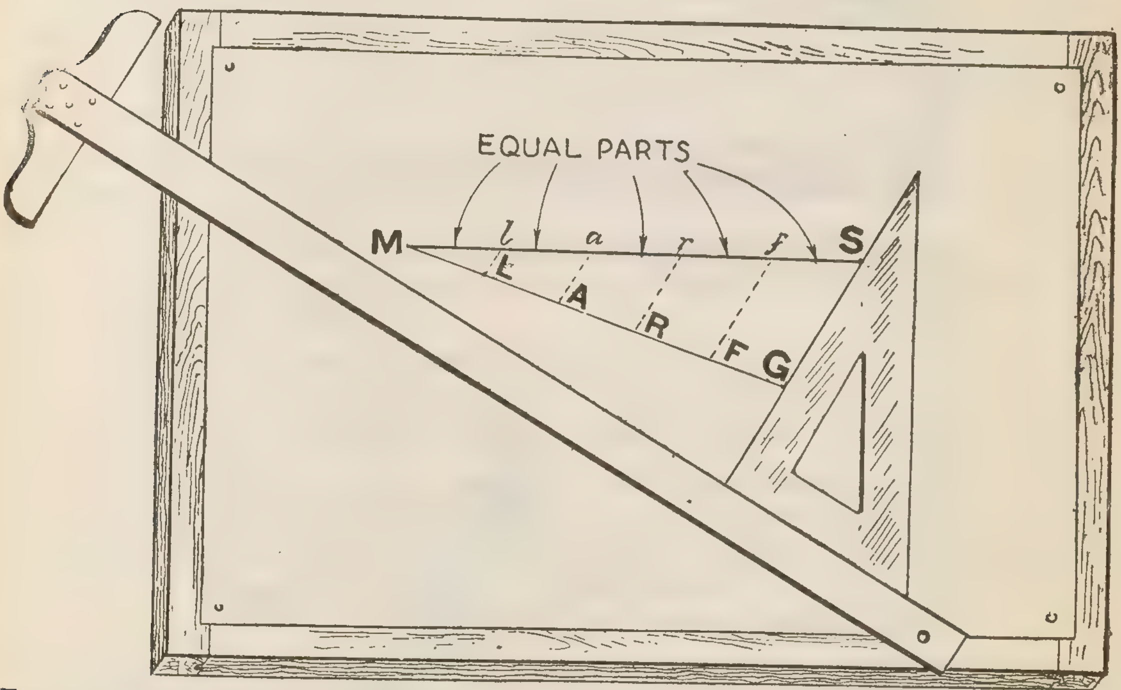
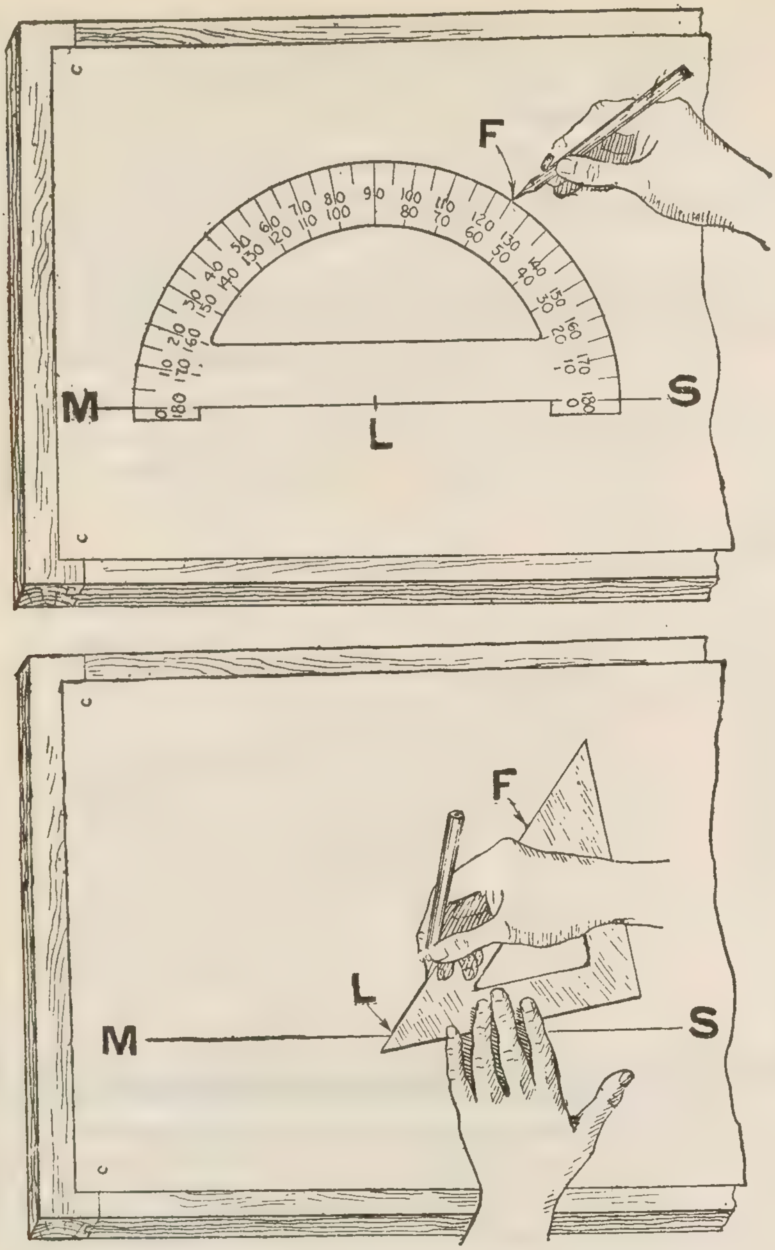


FIG. 9,164.—To divide a given line into any number of equal parts without use of dividers. Let MS, be the given line. From M, draw a diagonal line MG, of length in inches equal to the number of parts (say five) into which MS, is divided. Mark the inch divisions (L, A, R, F,) on MG, and join GS. With aid of T square and triangle, draw lines through L, A R, F, parallel to GS, giving the points *l*, *a*, *r*, *f*, on MS. These points divide MS, into the desired number of equal parts. Note new use of T square by inclining it to any desired degree, the head not being in contact with the edge of the board.

The thickness of the line is determined by the distance between the points of the blades, operated by the regulating screw. By separating or bringing together the blades, a thick or thin line may be drawn, as desired.

Arcs, or circles, are inked in by removing the pencil end and inserting the pen end into the compass leg, or by using the bow compass.



FIGS. 9,165 and 9,166.—Method of using the protractor to draw a line through a given point on a line and making a given angle with the line. Let MS and L, be respectively the given line and point on the line. Place protractor so that its center registers with point L, and its straight side with the line MS. Find angle on circular scale and mark same as at F Remove protractor and join LF, by aid of triangle as in fig. 9,166, obtaining the required angle FLS.

NOTE.—***Under no circumstances*** should the large size tacks be used; get the smallest and thus increase the life of the board, as no board can be expected to remain in condition if jumbo tacks or railroad spikes be used to fasten down the paper.

Tracings.—Whenever it is desired to have more than one copy of a drawing, a "tracing" is made of it and from this as many blue prints can be obtained as are required.

When a tracing is needed for making blue prints, a piece of tracing paper or tracing cloth of the same size as the drawing is placed over the original drawing and fastened to the board. This tracing paper or cloth is almost transparent; the tracing is a mechanical copy of a drawing made by reproducing its lines as seen through a transparent medium such as has been described and the lines of the drawing can be seen through it.

The surfaces of the tracing cloth are called the "glazed side" and the "dull side," or "front" and "back"; the glazed side has a smooth polished surface and the dull side is like a piece of ordinary linen cloth.

Drawing on tracing paper or cloth is effected by pencil and drawing pen as in ordinary work.

The tracing cloth must be fastened to the board, over the drawing by pins or thumb tacks; moisture or dampness should be carefully avoided and the drawing done, preferably, on the smooth side of the cloth.

When tracing cloth will not take ink readily a small quantity of pounce may be applied to the surface of the cloth and distributed evenly with a piece of cotton waste, chamois, or similar material, but the pounce should be thoroughly removed before applying the ink.

NOTE.—*Drawing to Scale.*—The meaning of this is, that the drawing when done bears a definite proportion to the full size of the particular part, or, in other words, is precisely the same as it would appear if viewed through a diminishing glass. When it is required to make a drawing to a reduced scale, that is, of a smaller size than the actual size of the object, say, for instance, ½ full size, every dimension of the object in the drawing must be one-half the actual size; in this case one inch on the object would be represented by ½ inch. Such a reduced drawing could be made with an ordinary rule. This, however, would require every size of the object to be divided by the proportion of the scale, which would entail a very great loss of time in calculations. This can be avoided by simply dividing the rule itself by 2, from the beginning. Such a rule or *scale* as it is generally called, will be divided in ½ inches, each half inch representing one full inch divided into ½, ¼, ⅛, 1/16, each of these representing the same proportions of the actual sizes of the object to be drawn. From this contracted scale the dimensions and measurements are laid off on the drawing. *A quarter size scale* is made by taking three inches to represent one foot. Each of the three inches will be divided into 12 parts representing inches, each one of these again will be divided in ½, ¼, ⅛, etc.; each one of these representing to a quarter size scale the actual sizes of ½, ¼, ⅛, 1/16 of an inch.

In making tracings the order to be followed is as follows: 1, ink in the small circles and curves; 2, ink in the larger circles and curves; 3, then all the horizontal lines, beginning at the top of the drawing and working downward; 4, next ink in all the vertical lines, commencing at the left and moving back to the right; 5, draw in the oblique lines; 6, in finishing the figuring and lettering should be done with India ink, thoroughly black.

"Erasing," in case of mistakes or errors, should be done with an ink eraser or a sharp, round erasing knife; the surface of the tracing cloth must be made smooth in those places where lines have been erased; this is accomplished by rubbing the cloth with soapstone or powdered pumice stone, applied with a soft cloth or with the finger. When a mistake made is so serious that it cannot be corrected by erasing, a piece of the tracing cloth may be cut out and a new one inserted in its place.

A finished tracing should be provided with the title of the drawing, the date, scale and the initials of the draughtsman.

Lettering.—When the information necessary to the reading of a drawing cannot be expressed by lines and scale dimensions, it must be indicated in the form of printed explanations, remarks, etc.

NOTE.—***Many concerns*** have rules of their own, directing their draughtsmen to use either the smooth or the rough side for all purposes; if there be no such rules, it is left to the judgment of the draughtsman. While it is immaterial which side of the cloth is used in tracing, however, if any mistakes be made and have to be corrected this can be done easier on the glazed side; on the contrary, if any *additions* must be made to the tracing, which have to be drawn in pencil first, the dull side will be found most convenient, as the pencil marks show plainer on the dull side.

CHAPTER 142

How to Read Drawings

There are various ways of representing objects in drawings, and a knowledge of these different methods is essential in order to intelligently read a drawing or blue print.

The various methods of illustrating an object by a drawing are:

1. Perspective
2. Cabinet projection
3. Isometric projection
4. Orthographic projection
5. Development of surfaces

Of these methods, the first three may be classed as "pictorial" in that they show the entire visible portion of the object in one view, whereas the fourth requires several views to fully present the object and may be called "descriptive."

It is this latter method that is most generally used and which requires a little study to comprehend it.

A perspective drawing shows an object as it really appears to the eye, but presents so many difficulties of construction that the projection methods have been devised to overcome them. These projection methods will accordingly be considered first before taking up perspective.

Cabinet Projection.—In this system of drawing, the lines of an object are drawn parallel to three axes, one of which is horizontal, a second vertical, and the third, inclined 45° to the horizontal, as in fig. 9,167. The vertical and horizontal axes lie in the plane of the paper, and the vertical and inclined axes

lie in a plane intended to appear to the eye as being at right angles to the plane of the paper.

These axes lie in planes at right angles to each other and are known as the horizontal, vertical and profile planes.

In cabinet projection it is to be remembered that

1. All horizontal measurements, parallel to the length of the object must be laid off parallel to the horizontal axis, in their actual sizes.

2. All vertical measurements, parallel to the height of the object, must be drawn parallel to the vertical axis in their actual sizes.

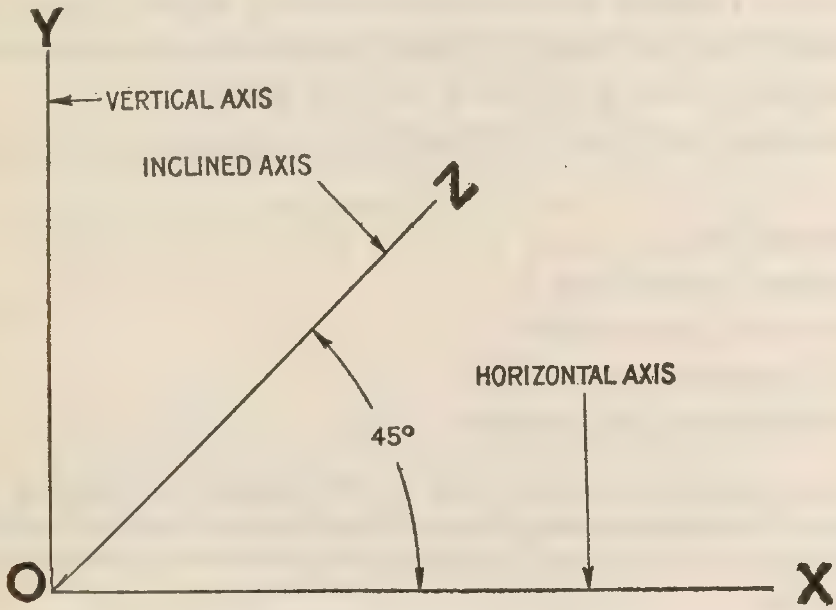


Fig. 9,167.—Cabinet projection axes.

3. All measurements parallel to the thickness of the object must be laid off on lines parallel to the 45° axis, in sizes of only one-half of the actual corresponding measurements.

It is not essential which side of the object should be considerered its length and which side its thickness.

Problem 1.—To draw a cube in cabinet projection.

First draw the three axes, OX, OY, OZ, as in fig. 9,168. Lay off OA,

and OC, on OX and OY, equal to side of the given cube, and complete the side by drawing CB and AB. On OZ, lay off OG, equal to ½ OA. Through C, draw a line parallel to OZ, and through G, a dotted line parallel to OY, giving the lines CF and GF. Similarly through points G,F,A and B, draw parallels to the axes, thus completing the cube.

In the drawing the face ABCO, is regarded as lying in the plane of the paper, the face DEFG, as parallel and the other faces ABED and OCFG,

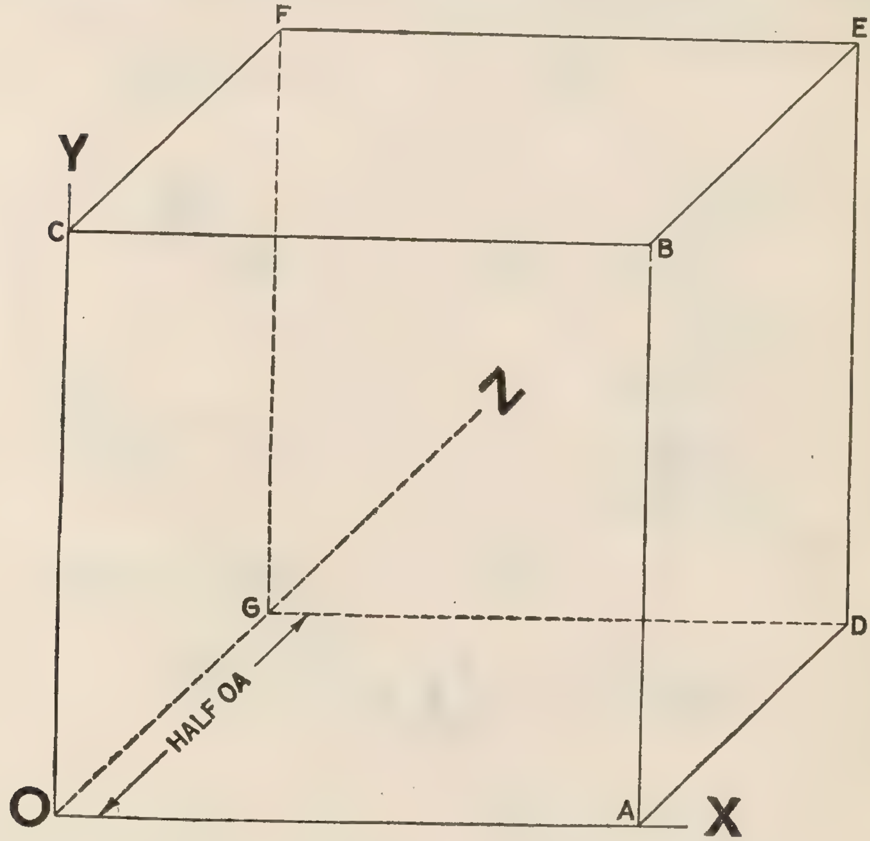


FIG. 9,168.—Cabinet projection of a cube.

as perpendicular to the plane of the paper. The edges which would be invisible if the cube were made of opaque material such as wood, are represented by dotted lines.

Problem 2.—To draw a right cylinder with its bases in the XOY, plane; length of cylinder 3 times the diameter.

This is the best position to draw a cylinder because the bases will be circles and the difficulty of describing ellipses avoided.

Draw the axes as usual. With O, as center and OA, equal to radius of cylinder, describe a circle. On OZ, lay off OM = 3 times OA (since length of cylinder = 3 times the diameter.)

With same radius describe a circle with M as center and draw tangents BC, and DE, thus completing the outline of the cylinder.

The portion of the circle about M, between C and E, is shown by dotted lines because it would be invisible if the cylinder were made of opaque material.

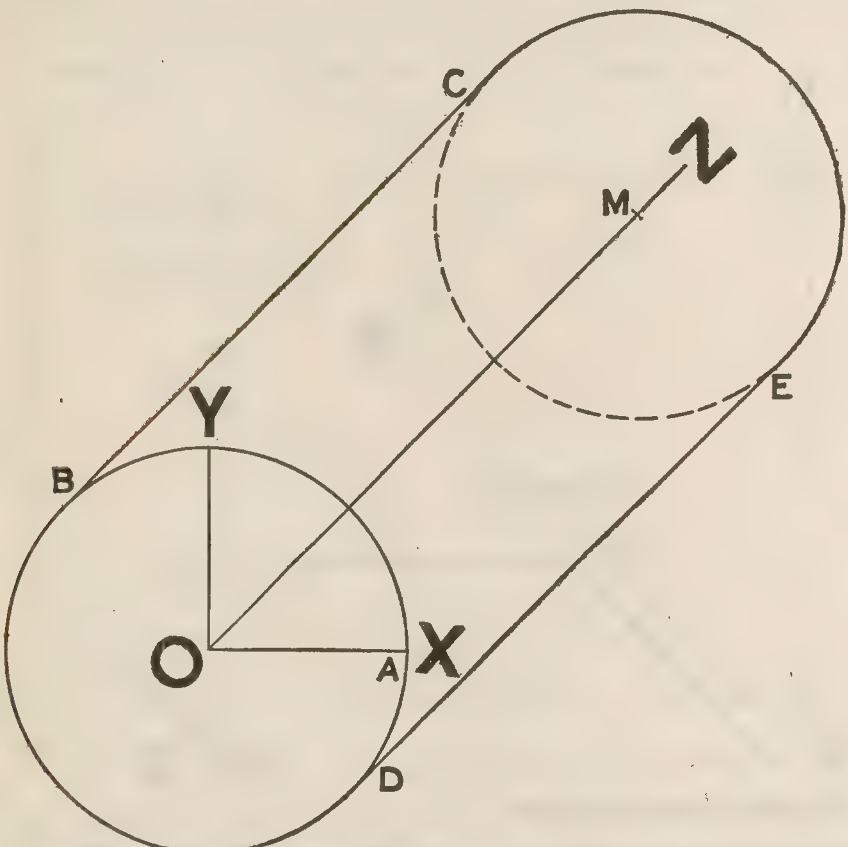


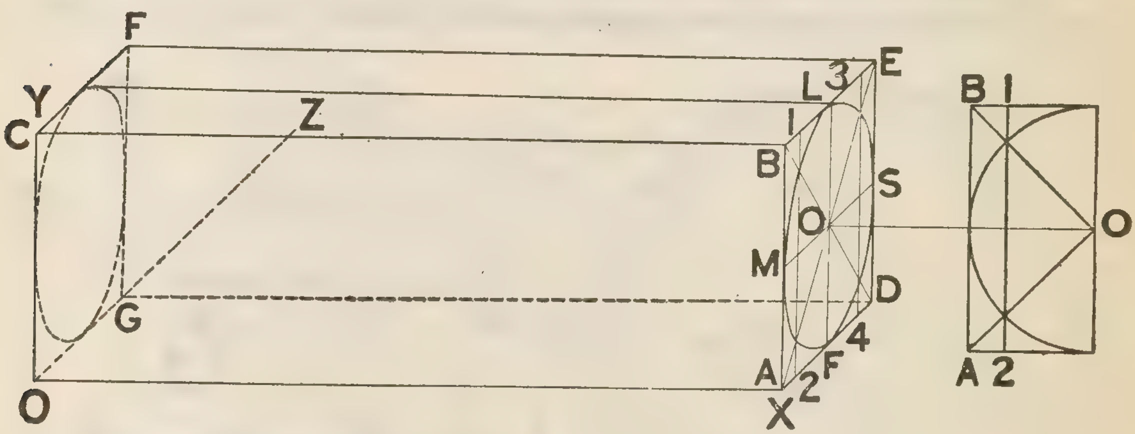
FIG. 9,169.—Cabinet projection of a cylinder with bases parallel to the plane of the paper.

Problem 3.—To draw a prism enclosing a cylinder with its bases parallel to the YOZ, plane; length of cylinder 3 times the diameter.

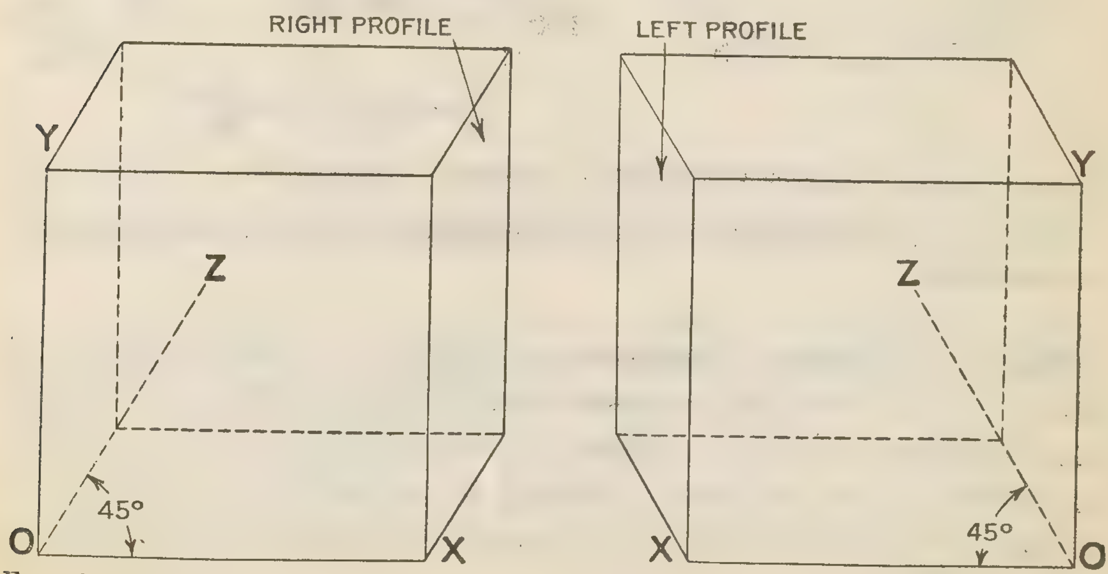
Draw in the cube as directed in problem 1, making AD = ⅙OA, as in fig. 9,170. Now, show half of the base ABED, in the plane of the paper as in

fig. 9,171. Here, draw diagonals OB and OA, and describe the half circle tangent to the sides. Through the intersection of the circle with diagonals draw line 12.

In fig. 9,170 make B1 = ½ of B1 in fig. 9,171 and draw line 12 in fig. 9,170, and by similar construction line 34. Next draw diagonals AE and BD. The intersection of lines 12 and 34, with these diagonals will give four points together with points M, L, S, F, through which to construct an ellipse representing the base of the cylinder as seen in profile constructing a similar ellipse at the other end and drawing the two tangents to the ellipses completes the outline of the cylinder.



FIGS. 9,170 and 9,171.—Cabinet projection of a prism enclosing a right cylinder with its bases parallel to the YOZ, plane.



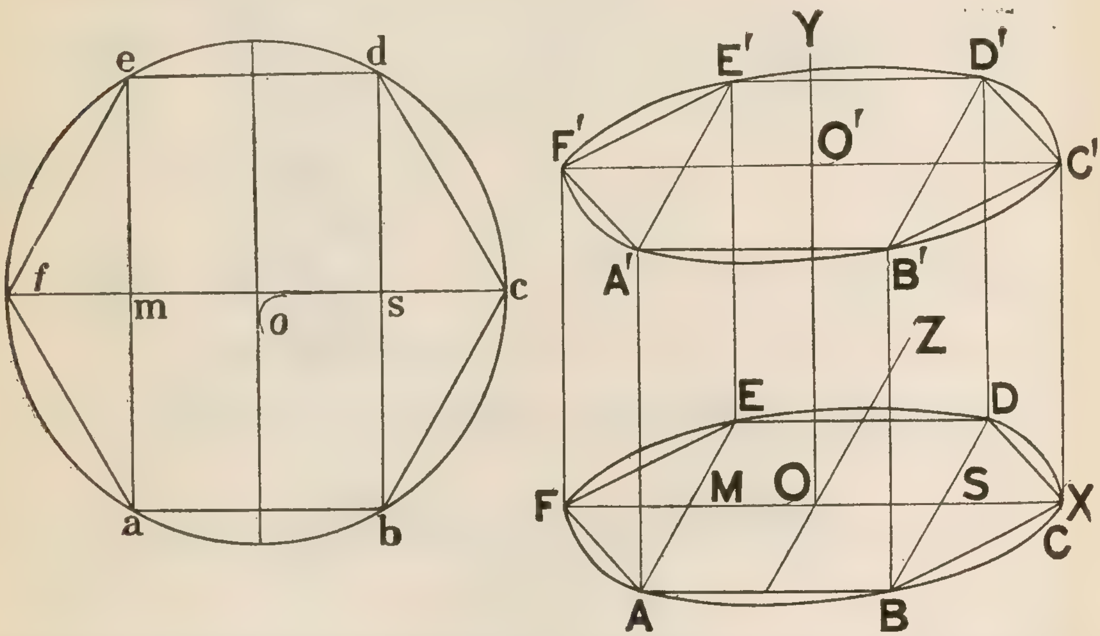
FIGS. 9,172 and 9,173.—45° cabinet projection with right and left profile.

Problem 4.—To draw a hexagonal prism inscribed in a right cylinder whose base equals twice the diameter.

In construction fig. 9,174, describe a circle of diameter equal to diameter of the cylinder. Inscribe a hexagon. In fig. 9,175 lay off OF and OC, equal to *of* and *oc*.

Transfer points *m*, *s*, obtaining M, S, and through M and S, draw lines parallel to OZ, and on these lines lay off ME = ½ *me;* MA = ½ *ma*, etc. Through the points thus obtained draw in the ellipse ABCDEF.

Similarly construct upper ellipse A′B′C′D′E′F′, at elevation OO′ = ¾ FC, and draw tangents thus completing the cylinder. Join AB, A′B′, BC,



Figs. 9,174 and 9,175.—Cabinet projection of a hexagonal prism inscribed in a right cylinder.

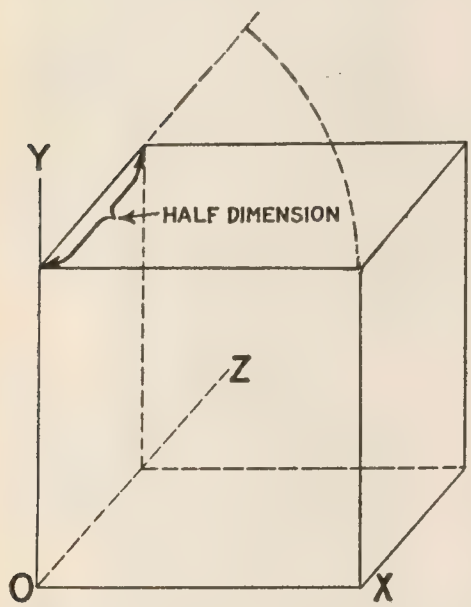
B′C′, etc., and AA′ BB′, etc., thus completing outline of inscribed hexagonal prism.

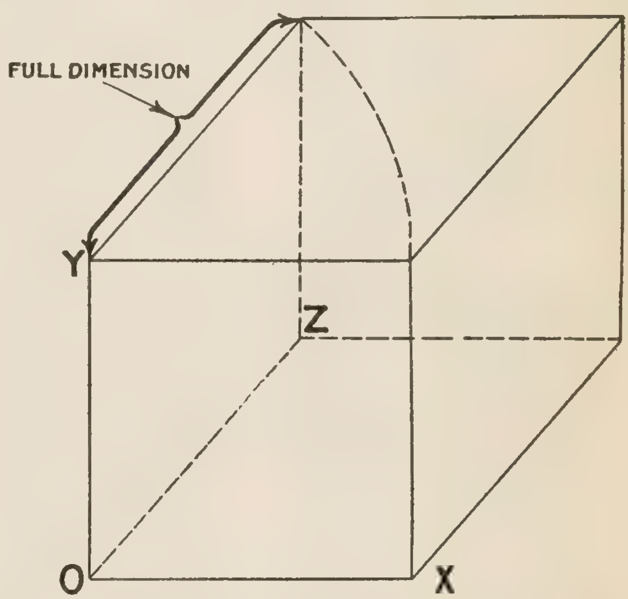
Modified Cabinet Projection.—There are various ways in which the 45° one-half foreshortened profile cabinet projection just described can be modified for convenience to suit special conditions. For instance, instead of inclining the OZ, axis to the right, as in fig. 9,172, it may be pointed to the left as in fig. 9,173.

Instead of foreshortening the profile dimension one half, as in fig. 9,176 in some cases, where dimensions are to be taken from the drawing, the profile may be made full dimension as in fig. 9,177.

Sometimes, because of the limited space available, it is desirable to take the OZ, axis at some angle other than 45°. In such cases it is usually taken at 30° or 60°, because these angles are obtained directly with the T square and triangles—the object of the projection system being to use these instruments to conveniently and quickly execute drawings. In special cases, obviously any angle may be taken to suit the conditions.

These modifications of cabinet projection are shown in figs. 9,178 to 9,180. The first three figures show the object in full

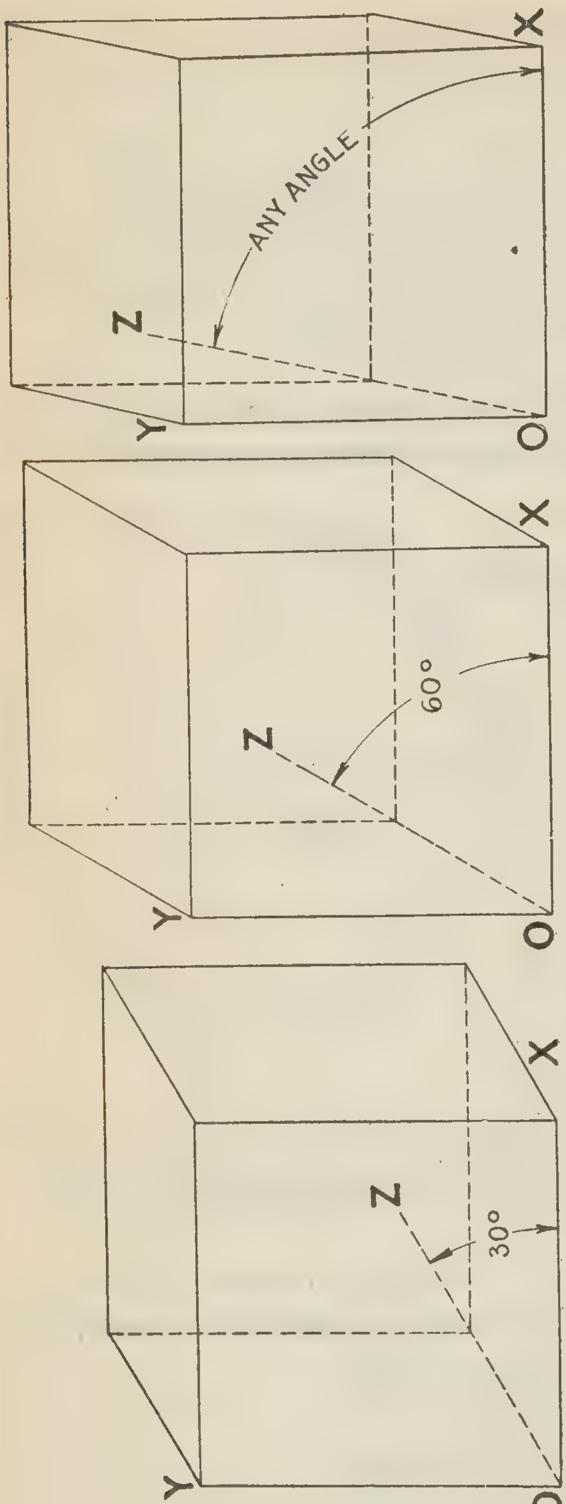




FIGS. 9,176 and 9,177.—Half and full profile dimension 45° cabinet projection. Evidently where all lines are drawn full dimension as in fig. 9,177, the drawing is made without calculating the profile dimensions, and especially in case of a complicated object time is saved.

profile dimension for comparison. However, to save space and approach the natural appearance of the object, the following are the approved proportions for the profile.

OZ axis 45°, profile half dimension
OZ axis 30°, profile two-thirds dimension
OZ axis 60°, profile one-third dimension



FIGS. 9,178 to 9,180.—Modified full profile dimension cabinet projection, with OZ axis at 30° (fig. 9,178); 60° (fig. 9,179), and at any angle (fig. 9,180). Evidently these modifications render the system flexible with respect to space and clear representation of any special part of an object.

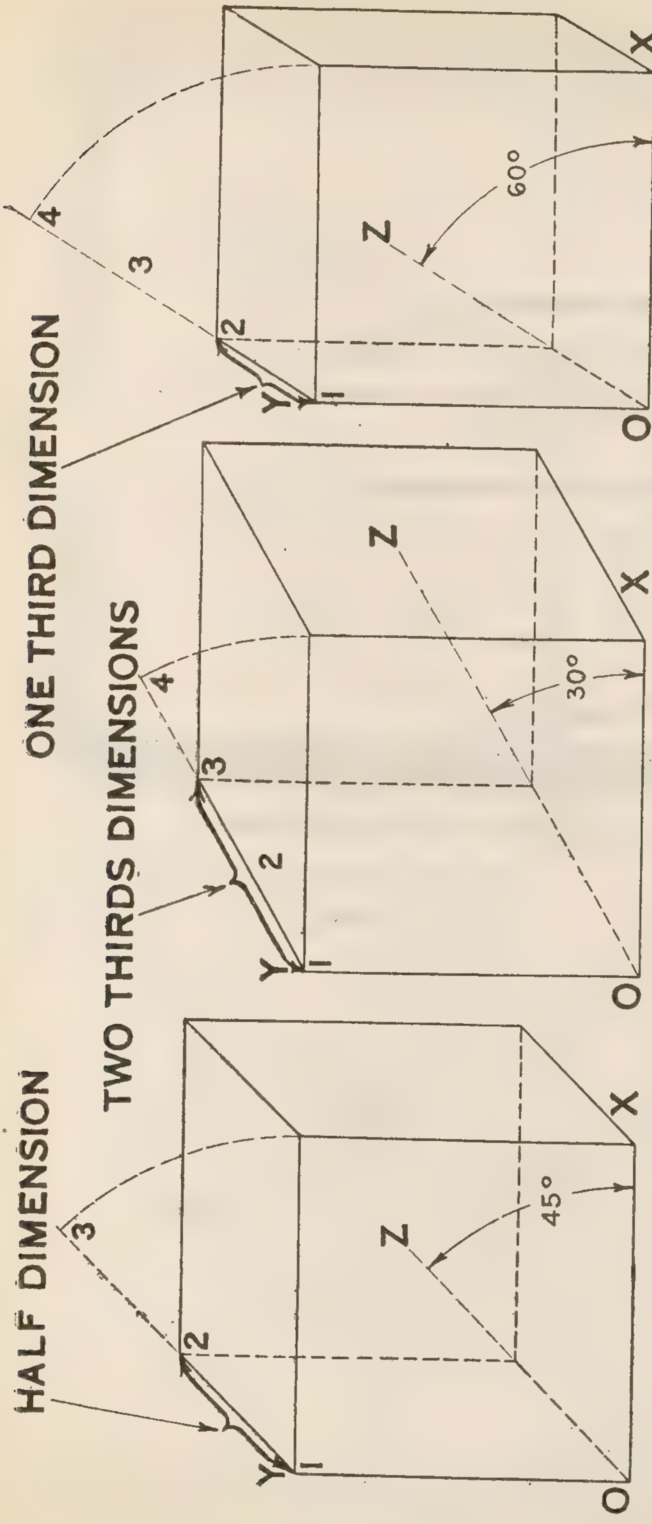
The appearance of an object drawn to these proportions is shown in figs. 9,178 to 9,180.

Isometric Projection.—By definition the word *isometric* means *equal distances*, and as here applied, isometric projection is a system of drawing *with measurements on an equal scale in every one of three sets of lines* 120° *apart and representing the three planes of dimension.*

In other words, the axes are taken 120° apart and there is no profile foreshortening as in cabinet projection, all lines being drawn full length.

Isometric projection further differs from cabinet projection in that none of the three planes lie in the plane of the paper.

Fig. 9,184 shows method of laying out the isometric axes using T square and 30° triangle. Figs. 9,185 and 9,186 show comparison of axes of the cabinet and isometric systems.



Figs. 9,181 to 9,183.—Approved proportions for profile dimensions of 45°, 30° and 60° cabinet projection.

Problem 5. — To draw a prism in isometric projection.

First draw the axes OX, OY and OZ, at 120° as explained in fig. 9,184.

From O, fig. 9,187, lay off on the axes just drawn OA = OB = OC = length of side of the cube. Through points A,B,C, thus obtained, draw lines parallel to the axes, giving points D,E,F, thus completing visible outline of the cube.

Through D, E and F, draw dotted lines intersecting at G, which gives the invisible outlines of the cube, assuming it to be opaque. An objection to this view is that the point G, falls behind the line OB, thus the outline of the invisible portion does not appear so well defined as it would in the case of a parallelopipedon as in the little fig. 1,605 at the right.

An objection to isometric projection is that, since no projection plane lies in the

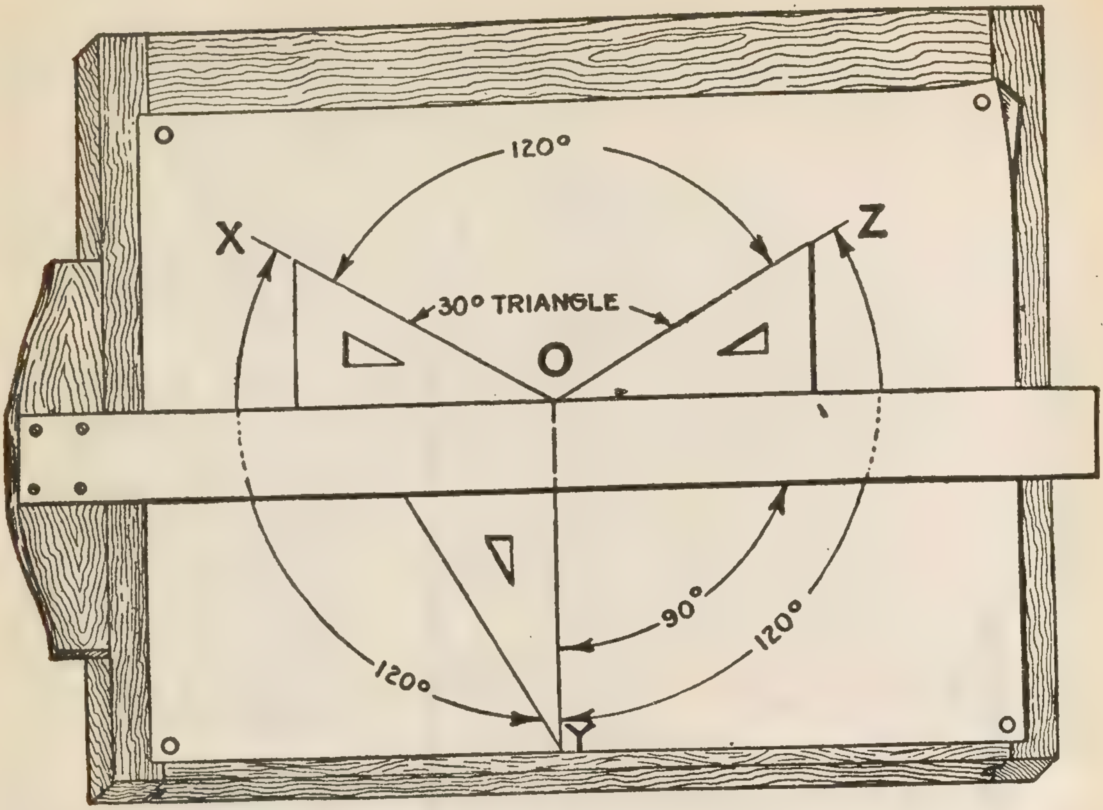
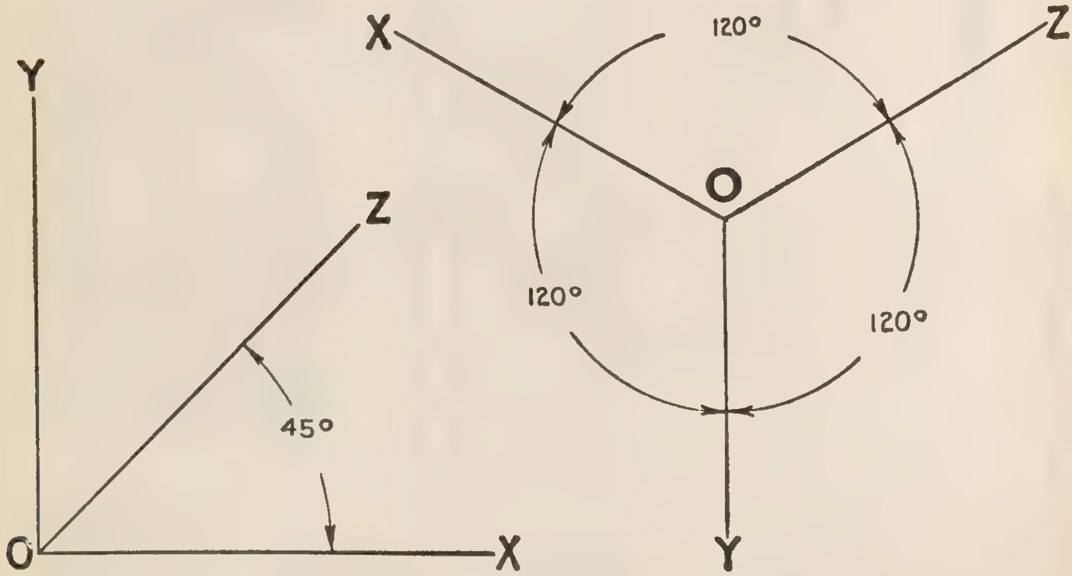


FIG. 9,184.—Isometric axes laid out at 120° to each other with 30° triangle and T square.



FIGS. 9,185 and 9,186.—Comparison of cabinet and isometric axes.

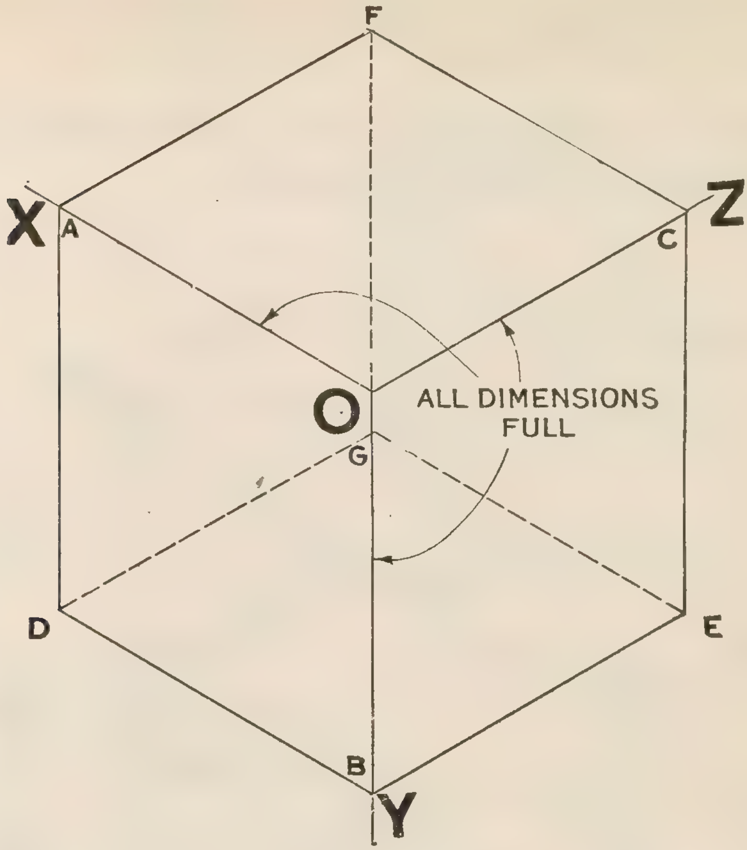


FIG. 9,187.—Isometric projection of a cube.

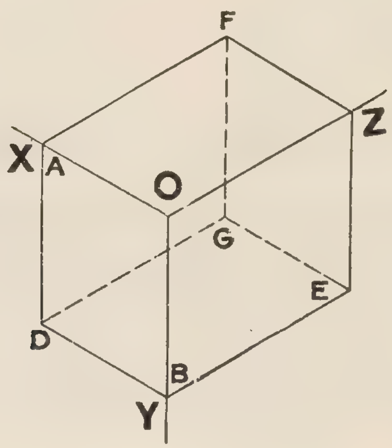
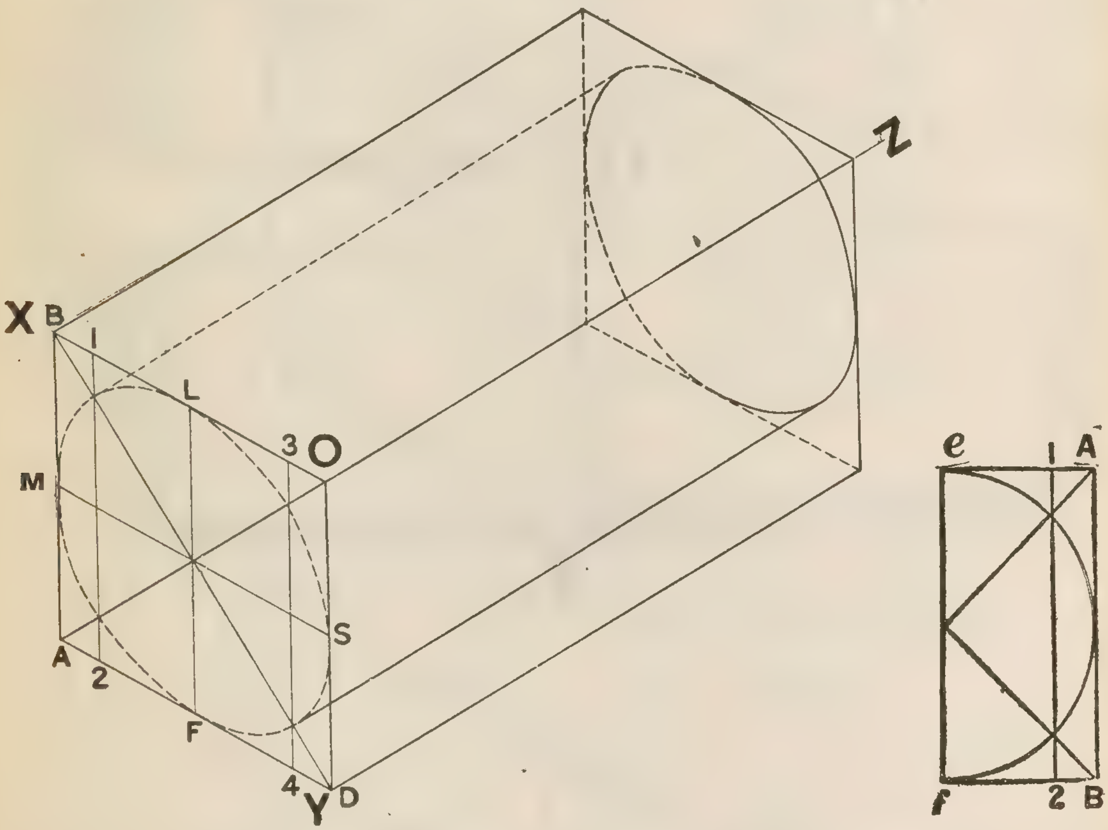


FIG. 9,188.—Isometric projection of a parallelopip·don showing completed dotted outline of invisible portion as compared with that of the cube fig. 9,187 in which part of the dotted line FG, falls behind OB. The reference letters are the same in both figures.

in the plane of the paper, it is necessary to construct ellipses to represent circular portions of an object and this requires time and skill.

Problem 6.—Draw a horizontal prism with inscribed cylinder; length of cylinder two times the diameter.

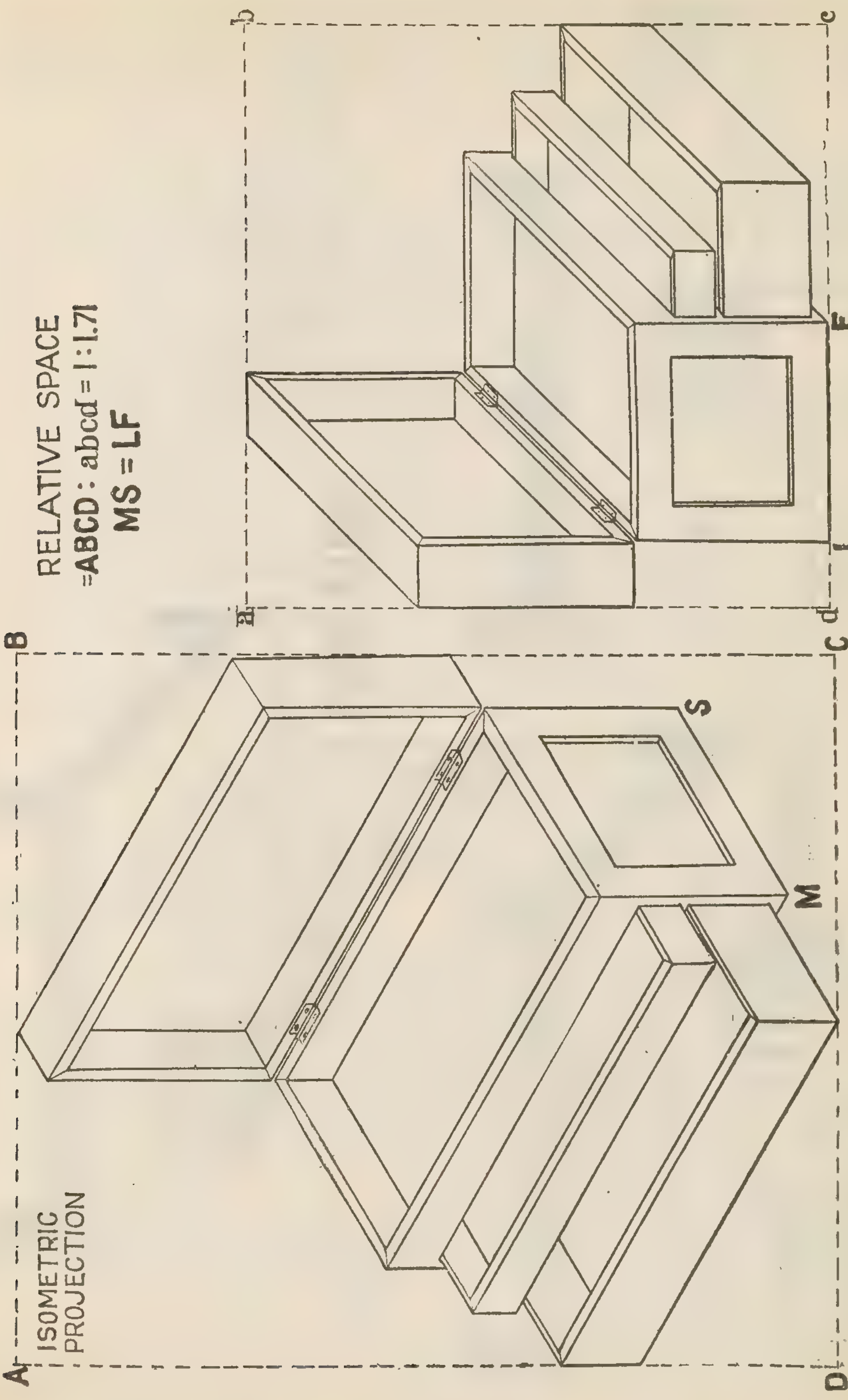


Figs. 9,189 and 9,190.—Isometric projection of a horizontal prism with inscribed cylinder.

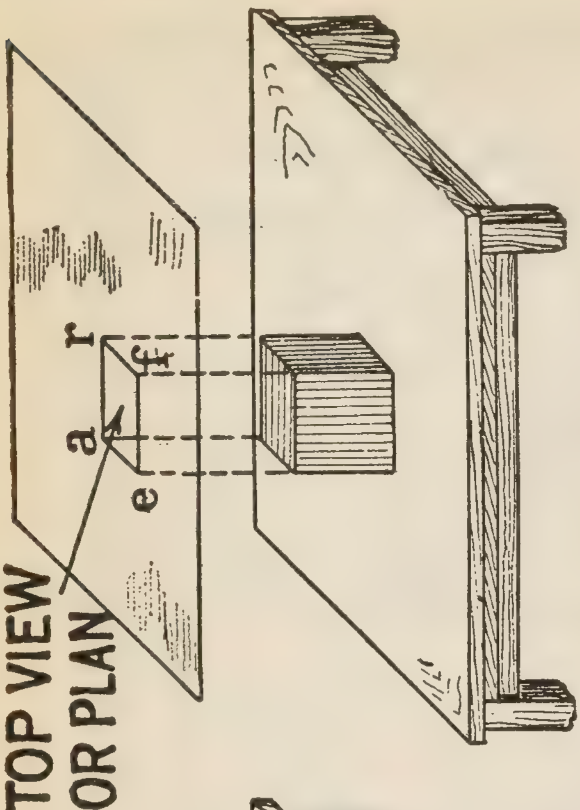
Draw the prism as explained in fig. 9,187, and draw in fig. 9,189, making its length twice its side. Now construct the half end view in plane of paper (fig. 9,190); describe circle, diagonals and intersecting line 12.

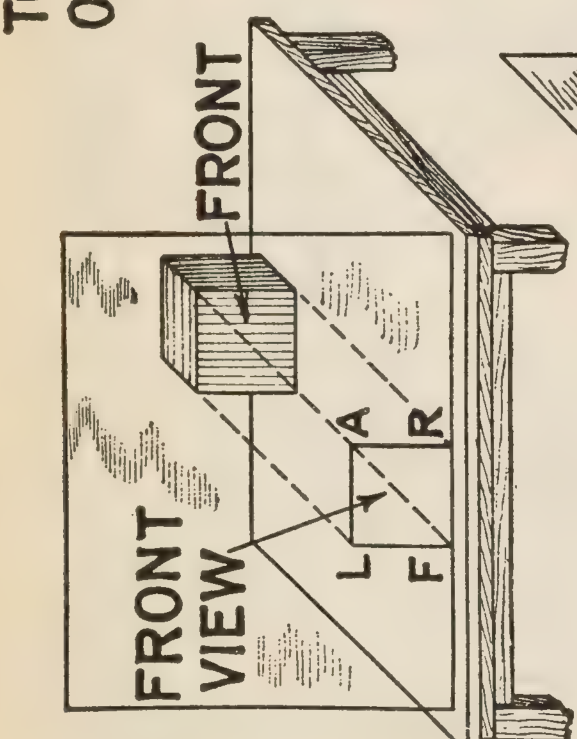
Transfer from fig. 9,190 line 12, to fig. 9,189 and draw symmetrical line 34, and diagonals. The intersections, together with points MS, and LF, of axial lines through the center, give eight points through which construct ellipse.

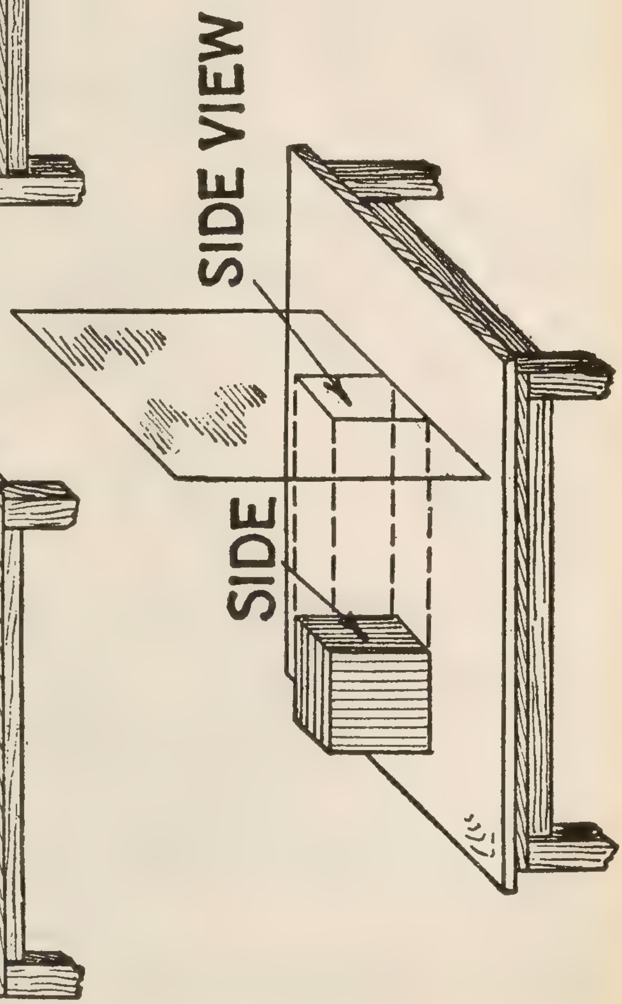
Construct also a similar ellipse at other end of prism and join two ellipses with tangents, thus completing outline of inscribed cylinder.



FIGS. 9,191 and 9,192.—Comparison of isometric and cabinet projection showing relative space required to represent the same object drawn to same scale. Note that dimension MS = LF. The saving in space by cabinet projection is due to the position of the axes and the foreshortening of the profile dimensions.







FIGS. 9,193 to 9,195.—Illustration of the various "views" of an object in orthographic projection by means of pane of glass placed in the different planes of projection.

An objection to isometric projection is the greater amount of space required as compared with cabinet projection; this point is shown in figs. 9,191 and 9,192.

Orthographic Projection.—Isometric drawing and cabinet projection, while showing the object as it really appears to the eye of the observer, are neither of them very convenient methods to employ where it is necessary to measure every part of the drawing for the purpose of reproducing it.

Drawings suitable for this purpose, generally known as *working drawings*, are made by the method known as *orthographic projection*.

In cabinet or isometric projections, three sides of the object are shown in one view, while in a drawing made in orthographic projection, but one side of the object is shown in a single view.

To illustrate this, a clear pane of glass may be placed in front of the object intended to be represented.

In fig. 9,193 a cube is shown on a table; in front of it, parallel to one face (the front face) of the cube, the pane of glass is placed.

Now, when the observer looks directly at the front of an object from a considerable distance, he will see only one side, in this case only the front side of the cube.

The rays of light falling upon the cube are reflected into the eyes of the observer, and in this manner he sees the cube. The pane of glass, evidently, is placed so that the rays of light from the object will pass through the glass on straight lines, to the eye of the observer. The front side of the object, by its outline, may be traced upon the glass, and in this manner a figure drawn on it (in this case a square) which is the view of the object as seen from the front which in this case is called the *front elevation*.

One view, however, is not sufficient to show the real form of a solid figure. In a single view two dimensions only can be shown, length and height; hence the thickness of an object will have to be shown by still another view of it, as the top view or *plan*.

Now, place the pane in a horizontal position above the cube which is resting on the table, as in fig. 9,194, and looking at it from above, directly

over the top face of the cube, trace its outline upon the pane; as a result a square figure is drawn upon the glass, which corresponds to the appearance of the cube, as seen from above. This square on the glass is the top view of the cube, or its *plan*.

Fig. 9,195 shows the manner in which a side view of the cube may be traced; the glass is placed on the side of the cube, which rests on the table

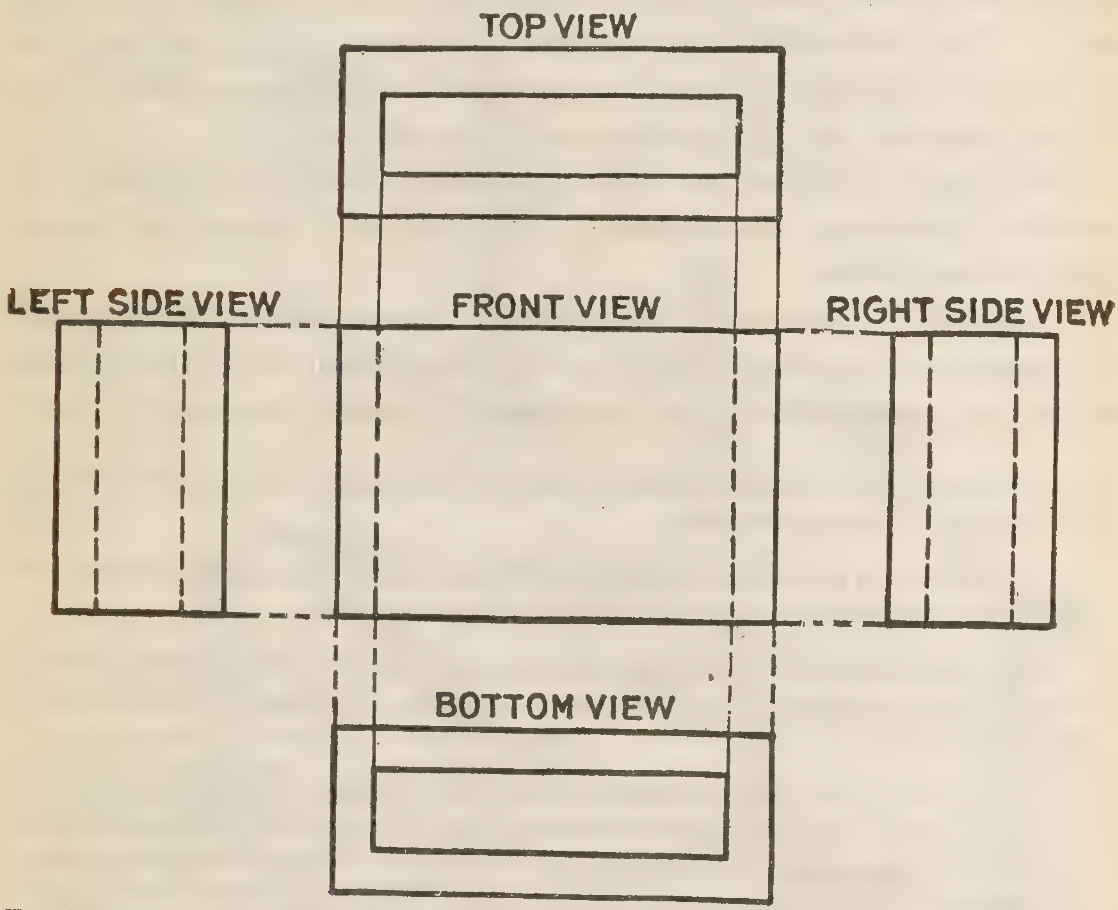


FIG. 9,196.—Five views of an object as drawn in orthographic projection.

as before, and the outline of the cube on the glass in this position, is called its *side elevation*.

Usually either two of the above mentioned views will suffice to show all dimensions and forms of the object, but to completely represent complicated objects, three or four views may be required.

In complicated pieces of machinery, however, more views, three and even more may be required to adequately represent the proportions and form of the different parts.

A drawing which represents the object as seen by an observer looking at it from the right side is called *the right side elevation* and a drawing showing the object as it appears to the observer looking at it from the left side is called *the left side elevation.*

In the case of a long object, a view at the end is called an *end view.*

A view of the object as seen from the rear is called the *rear view* or *rear elevation,* and a view from the bottom, the *bottom view.*

The different views of an object are always arranged on the drawing in a certain fixed and generally adopted manner.

The front view is placed in the center; the right side view is placed to the right of the front view, and the left side view to the left; the top view is placed above the front view and the bottom view below it. The different views are placed directly opposite each other and are joined by dotted lines called *projection lines.*

By the aid of projection lines, leading from one view to the other, as in fig. 9,196, measurements of one kind may be transmitted from one view to the other; for instance, the height of different parts of an object may be transmitted from the front view to either one of the side views; in like manner the length of different parts of the object may be transmitted by the aid of projection lines, to the bottom view and top view.

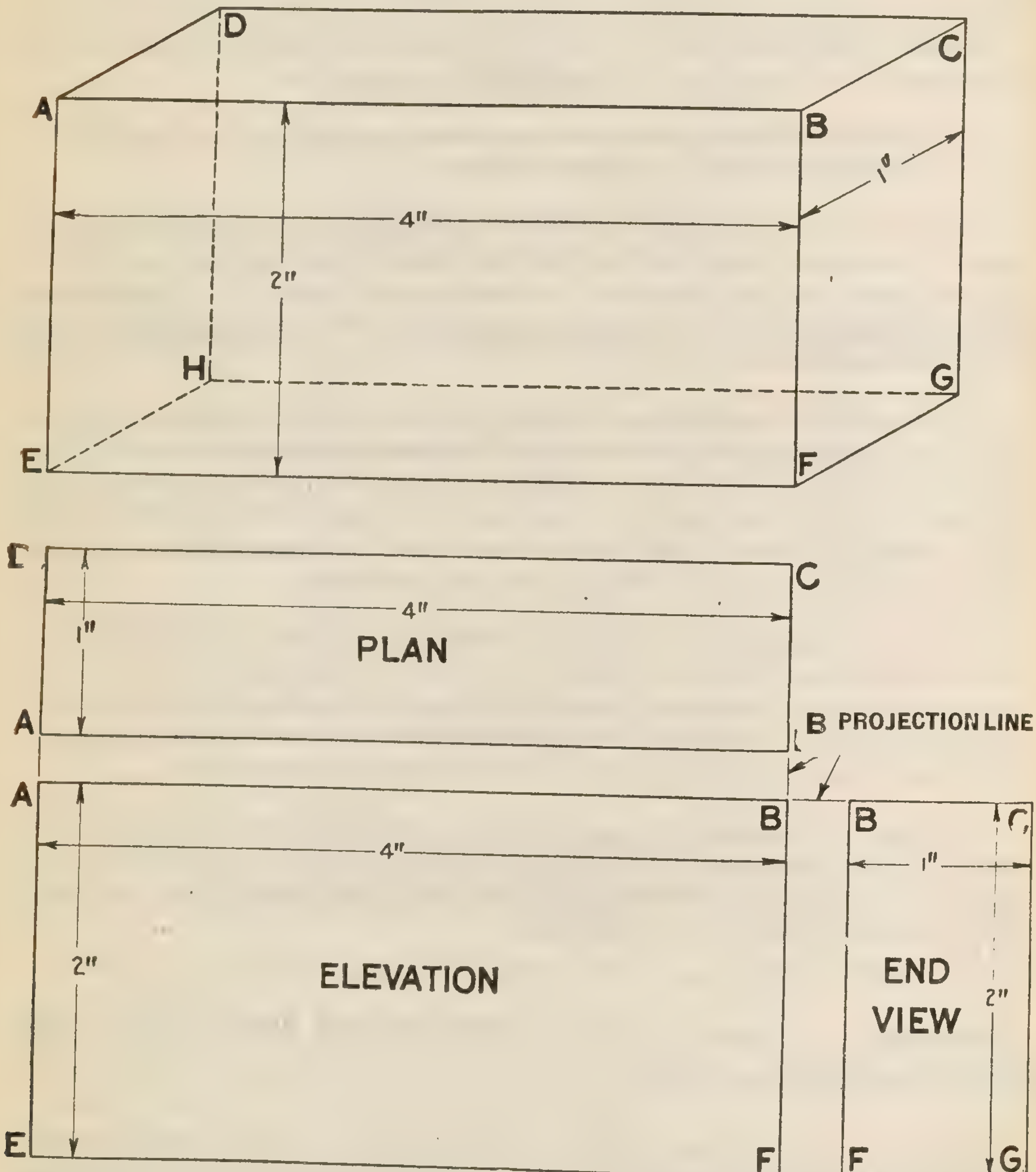
It is often desirable to show lines belonging to an object, although they may not be directly visible. In fig. 9,196 the top view and the bottom view show plainly that the object is hollow; looking at the object from the front or from the sides, however, the observer could not see the inside edges of the object, except it were made of some transparent material.

In projection drawing it is assumed for convenience that all objects are made of such material, transparent enough to show all hidden lines no matter from which side the object is observed; these hidden lines are represented in the drawing by dotted lines.

Problem 7.—Draw a plan, elevation and end view of the prism shown in fig. 9,197.

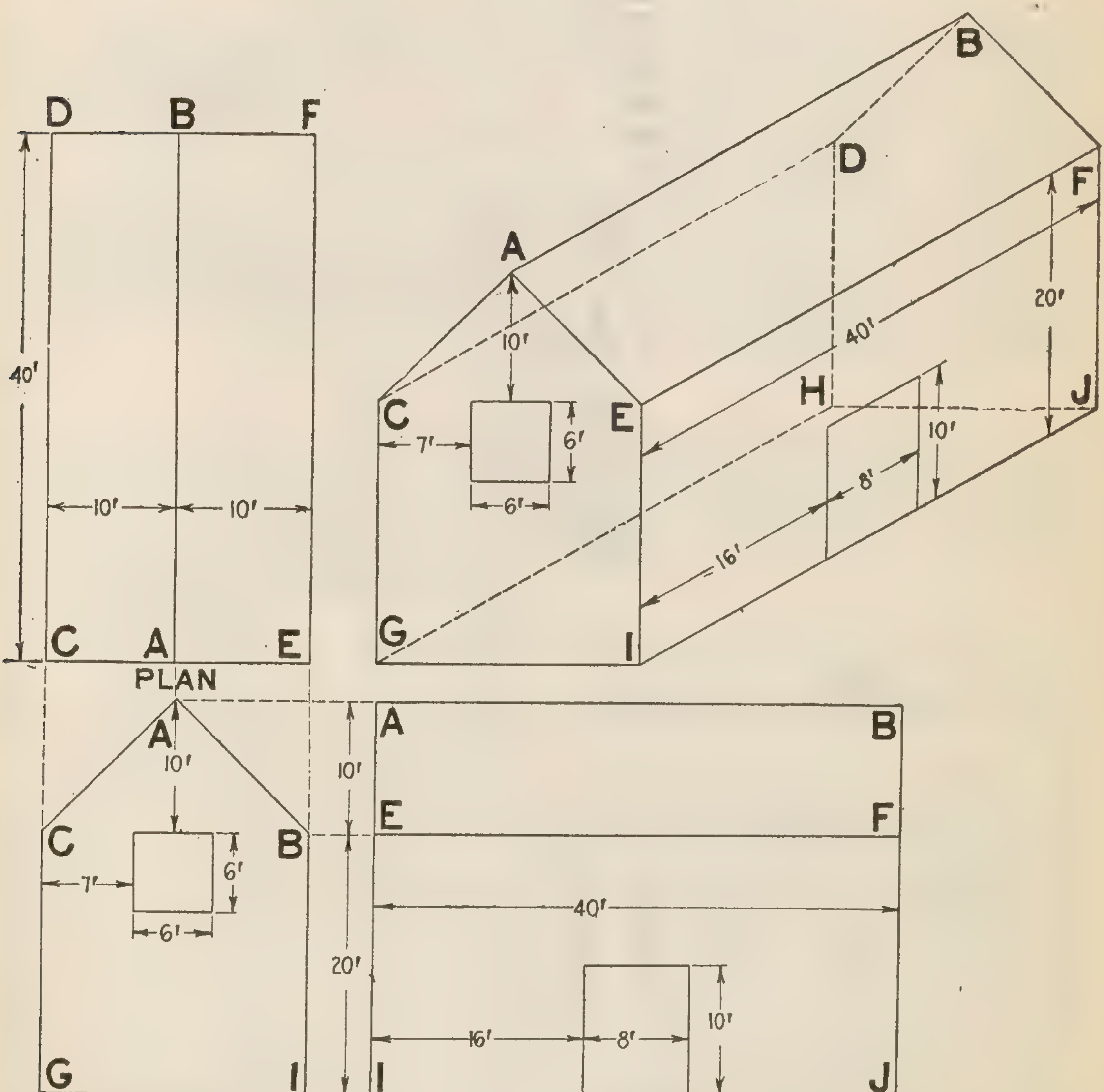
First draw the top view or plan as in fig. 9,198, by drawing the rectangle ABCD, to scale making AB, = 1 in. and AD, 4 ins. For the elevation, project the points A and B, down to the parallel line obtaining line AB.

Lay off AE = 2 ins. and complete rectangle giving ABFE, or elevation. The end view BCGF, is drawn in a similar manner, side BF, being obtained by projection and BC, by measurement.

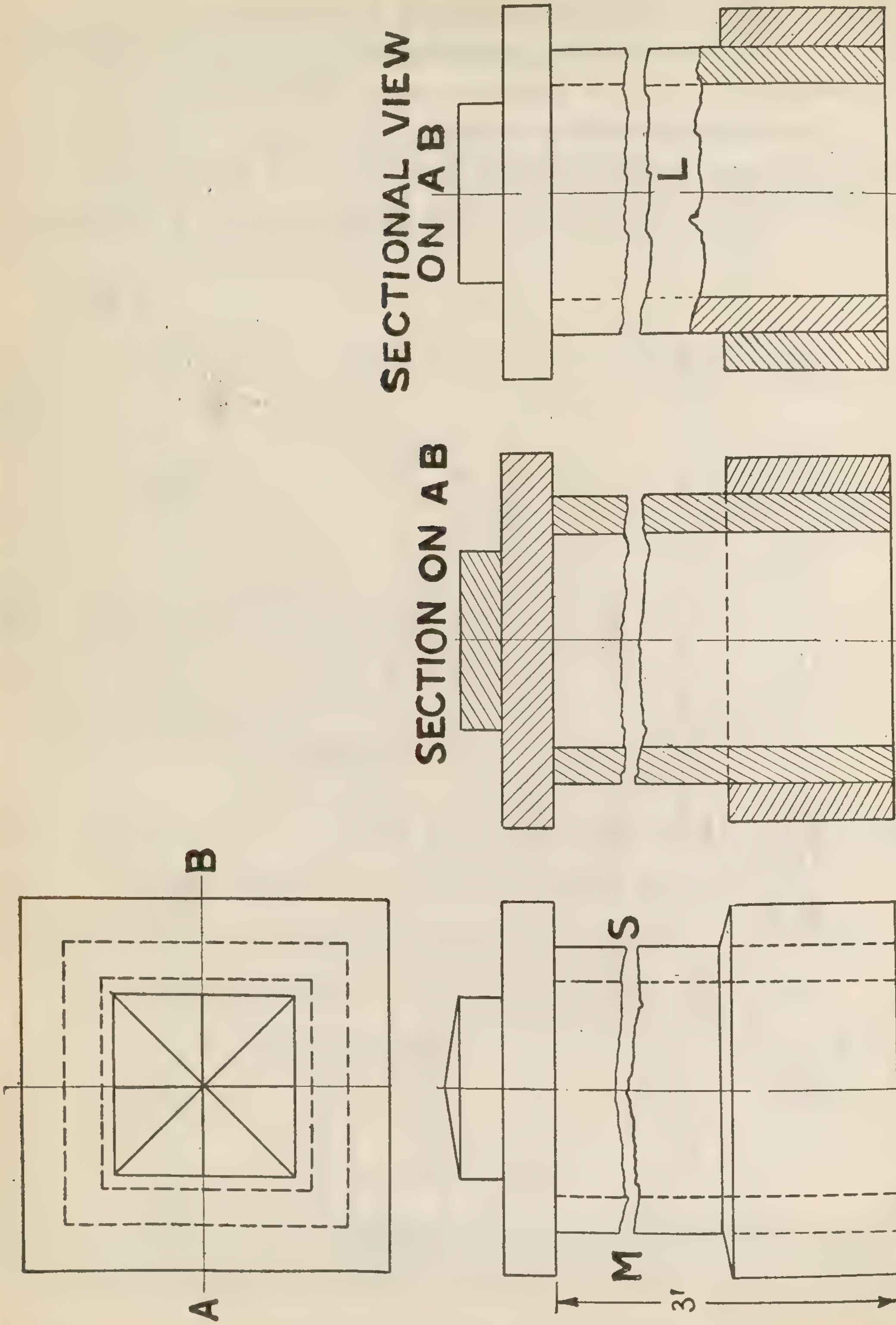


FIGS. 9,197 and 9,198.—Cabinet projection of a prism, and orthographic views of same, being shown in plan, elevation and end view.

Center Lines.—Objects which are symmetrical with respect to some axis drawn through the center are most easily drawn by first drawing such axis or *center line* and then drawing the object so that its center coincides with the center line. It is usual to make such lines broken by dot and dash, to distinguish them from the lines of the object. The author, however, prefers to



Figs. 9,199 and 9,200.—Cabinet projection outline drawing of a barn and same drawn in orthographic projection.



FIGS. 9,201 to 9,204.—Orthographic projection drawings of a built up post illustrating center lines, section, and sectional view also the method of reducing space required for drawing of a long object by "breaking it off" as at MS.

draw solid center lines, obtaining the proper contrast to avoid confusion by drawing them much finer than those of the object, the same method being used also for dimension lines.

Figs. 9,201 and 9,202 show a rectangular built-up post drawn with center lines. Evidently since the figure is symmetrical with respect to these lines, equidistances are conveniently spaced off each side by aid of dividers and the drawing made quickly and with precision.

Since to show the entire length of the post would require considerable space, it is usual to "break it off" as at MS, by two ragged free hand lines, which indicate that part of its length is not shown. The construction of the post may be more clearly shown by drawing it as though it were sawed through from end to end along the line AB; thus showing only the half back of AB; it would then have the appearance as shown in fig. 9,203, called a *section* on AB. The surface assumed to be sawed is "section lined." That is, covered with a series of parallel lines usually inclined 45°, 30° or 60°. It will be noted that the section lines in one plank run in a different direction from those in an adjacent plank so as to distinguish the separate parts.

To draw section lines consumes time, hence, time may be saved by showing in section not more than is sufficient for clearness, the rest of the drawing being seen "in full" as in fig. 9,204; this is called a sectional view. Here the post is shown in full down to the ragged line L, below this line the post is considered as being cut away to the axis AB.

Development of Surfaces.—The principles of projection already explained may be readily applied to the important problem of development of surfaces.

Whenever it is necessary to make an object of some thin material like sheet metal, as in the case of elbows or tees for leader or stove pipe, the surface of the desired object is laid out on sheet metal, in one or in several pieces; these are called the patterns of the object; the pattern being first laid out on the sheet metal and then cut out; when this is done the separate pieces are ready to be fitted together to form the required object.

The method by which the surface of an object is laid out on a plane is called *the* ***development*** *of the object.*

This subject is treated at considerable length in the chapters on "Principles of Pattern Cutting" and "Sheet Metal Problems."

CHAPTER 143

Geometry

By definition geometry is *that branch of pure mathematics which treats of space and its relations; the science of the mutual relations of points, lines, angles, surfaces, and solids, considered as having no properties except those arising from extension and difference of location.* There are several divisions of geometry, classed

1. With respect to the *medium* of application, as
   a. Analytical
   b. Descriptive

2. With respect to the nature of the figures
   a. Plane
   b. Solid
   c. Spherical

Analytical geometry is that branch in which position is indicated by algebraic symbols and the reasoning conducted by analytic operations.

NOTE.—***One classification*** divides geometry into seven distinct sections: 1, Euclidean geometry, comprising the principles presented by Euclid about 300 B.C. 2, projective geometry, a development of Euclidean geometry. 3, descriptive geometry, used in engineering drawing. 4, analytical geometry, the relation between geometry and algebra. 5, line geometry. 6, non-Euclidean geometry, dealing with imaginary space elements. 7, axioms of geometry, a critical analysis of the science.

Descriptive geometry is that branch in which the relations of lines and figures in space are structures through *their projections* on two planes.

Plane geometry is that branch which treats about relations in a plane.

Solid geometry is that branch which includes all three dimensions of space.

Spherical geometry is that branch which treats of figures drawn upon the surface of a sphere.

The two branches of geometry essential to the sheet metal worker are plane geometry and descriptive geometry. Accordingly he should have at least an elementary knowledge of the subject in order to properly lay out sheet metal patterns. The definitions which follow are given so that the student will understand the technical terms used.

Definition

Altitude.—The elevation of an object above its base, or the perpendicular distance between the top and bottom of a figure.

Angle.—The difference in direction of two lines which meet or tend to meet. The lines are called the sides and the point of meeting, the vertex of the lines. Angles are distinguished in respect to magnitude by the terms right, acute and obtuse angles.

Apex.—The summit or highest point of an object.

Arc.—Part of the circumference of a circle.

Axis of a Solid.—An imaginary straight line passing through its center.

Axis of a Figure.—A straight line passing through the center of a figure, and dividing it into two equal parts.

Base.—The lowest part.

Bisect.—To divide into two equal parts.

Bisector.—A line which bisects.

Circle—A plane figure bounded by one uniformly curved line, all of the points in which are at the same distance from a certain point within, called the center.

Circumscribe.—To draw a line of figures about or outside, such as a circle drawn around a square touching its corners or angles.

Concave.—Curving inwardly.

Cone.—A solid body or figure having a circle for its base, and its top terminating in a point or vertex.

Construction.—The making of any object

Contour.—The outline of the general appearance of an object.

Convergence.—Lines extending toward a common point.

Convex.—Rising or swelling into a round form—the opposite to concave.

Corner.—The point of meeting of the edges of a solid, or the two sides of a plane figure.

Cross-hatching.—In free hand drawing the use of lines crossing each other to produce light and shade effects.

Curve.—A line of which no part is straight.

Cylinder.—A solid bounded by a curved surface and by two opposite faces called bases; the bases may be any curved figures and give the name to the cylinder; this a circular cylinder is one whose bases are circles.

Cylindrical.—Having the general form of a cylinder.

Degree.—The 360th part of a circle.

Describe.—To make or draw a curved line; to draw a plan.

Design.—Any arrangement or combination to produce desired results in industry or art. To delineate a form or figure by drawing the outline—a sketch.

Develop.—To unroll or lay out.

Diagonal.—A right line drawn from angle to angle of a quadrilateral or many angled figure and dividing it into two parts.

Diameter.—A right line passing through the center of a circle or other round figure terminated by the curve and dividing the figure symmetrically into two equal parts.

Edge.—The intersection of any two surfaces.

Elevation.—The term elevation, vertical projection and front view—applied to drawings—all have the same meaning.

Face.—One of the plane surfaces of a solid; it may be bounded by straight or curved edges.

Finishing.—Completing a drawing whose lines have been determined by erasing unnecessary lines and strengthening and accentuating where this is needed.

Foreshortening.—Apparent decrease in length, owing to objects being viewed obliquely; thus a wheel, when seen obliquely, instead of appearing round, presents the appearance of an ellipse.

Free-hand.—Executed by the hand unaided by instruments.

Generated.—Produced by.

Geometric.—According to geometry.

Half-tint.—The shading produced by means of parallel equidistant lines.

Hemisphere.—Half a sphere obtained by bisecting a sphere by a plane.

Horizontal.—Parallel to the surface of smooth water. In drawing, a line drawn parallel to the top and bottom of the sheet is called horizontal.

Inscribe.—See circumscribe—its opposite.

Instrumental.—By the use of instruments.

Longitudinal.—In the direction of the length of an object.

Model.—A form used for study.

Oblique.—Neither horizontal nor vertical.

Oblong.—A rectangle with unequal sides.

Oval.—A plane figure resembling the longitudinal section of an egg; or elliptical in shape.

Overall.—The entire length.

Parallel.—Having the same direction and everywhere equally distant.

Pattern.—That which is used as a guide or copy in making things.

Perimeter.—The boundry of a closed plane figure.

Periphery.—Circumference.

Perpendicular.—At an angle of 90°.

Perspective.—View; drawing objects as they appear to the eye from any given distance and situation, real or imaginary.

Plan.—Plan, horizontal projection and top view have the same meaning.

Plane Figure.—A part of a plane surface bounded by straight or curve lines, or by both combined.

Polygon.—A plane figure bounded by straight lines called the sides of the polygon. The least number of sides that can bound a polygon is three. Polygons bounded by a greater number of sides than four are denominated only by the number of sides.

Polyhedron.—A solid bounded by planes.

Prism.—A solid whose bases or ends are very similar plane figures, and whose sides are parallelograms; prisms are called triangular, square, etc. according as the bases are triangles, squares, etc.

Produce.—To continue or extend.

Projection.—The view of an object obtained upon a plane by projecting lines perpendicular to the plane.

Quadrant.—The fourth part; a quarter; the quarter of a circle.

Quadrisect.—To divide into four equal parts.

Rectangle.—A rectangle is a parallelogram having its angles right angles.

Section.—A projection upon a plane parallel to a cutting plane which intersects any object. The section generally represents the part behind the cutting plane, and represents the cut surfaces by diagonal lines.

Sectional.—Showing the section made by a plane.

Shadow.—Shade and shadow have the same meaning.

Solid.—A solid has three dimensions—length, breadth and thickness.

Sphere.—A solid bounded by a curved surface every point of which is equally distant from a point within called the center.

Surface.—The boundary of a solid. It has but two dimensions—length and breadth.

Symmetry.—A proper adjustment or adaptation of parts to one another and to the whole.

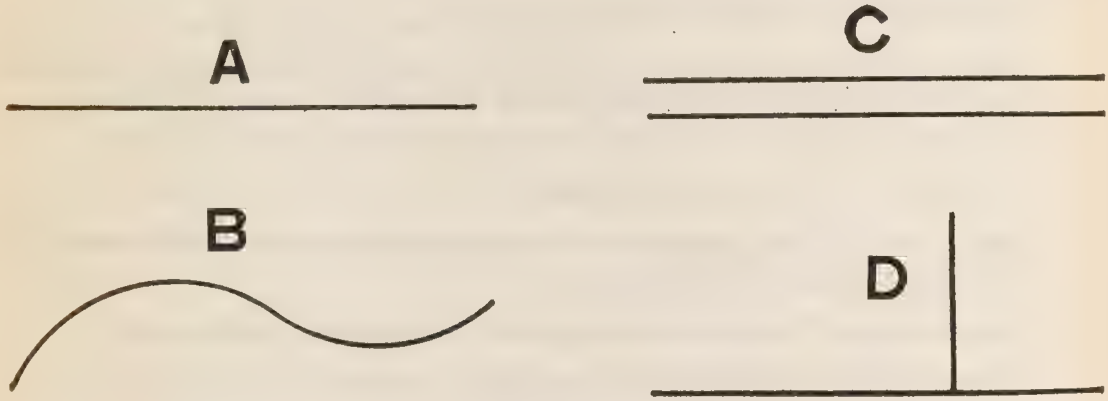
Trisect.—To divide into three equal parts.

Triangle.—A triangle is a polygon having three sides and three angles. Tri is a Latin prefix signifying three; hence a triangle is literally a figure containing three angles.

Vertical.—Upright or perpendicular. Vertical and perpendicular are not synonymous terms.

Vertex.—See angle, quadrilateral, triangle. The vertex of a solid is the point in which its axis intersects the lateral surface.

View.—See Elevation. Views are called front, top, right or left side, back or bottom, according as they are made on the different planes of projection. They are also sometimes named according to the part of the object shown, as edge view, end view, or face view.



FIGS. 9,205 to 9,208.—Various lines. A, straight; B, curved; C, parallel; D, perpendicular.

Working Drawing.—One which gives all the information necessary to enable the workman to construct the object.

Plane Geometry

Lines.—There are two kinds of lines: straight and curved. A straight line is *the shortest distance between two points*. A curved line is *one which changes its direction at every point*. Two lines are said to be parallel *when they have the same direction*. A horizontal line is *one parallel to the horizon or surface of the water*. A line is perpendicular with another line *when it inclines no more to one side than the other*.

Propositions Relating to Lines

1. *If two lines intersect, then the opposite angles formed by the intersecting lines are equal.*

In fig. 9,211.

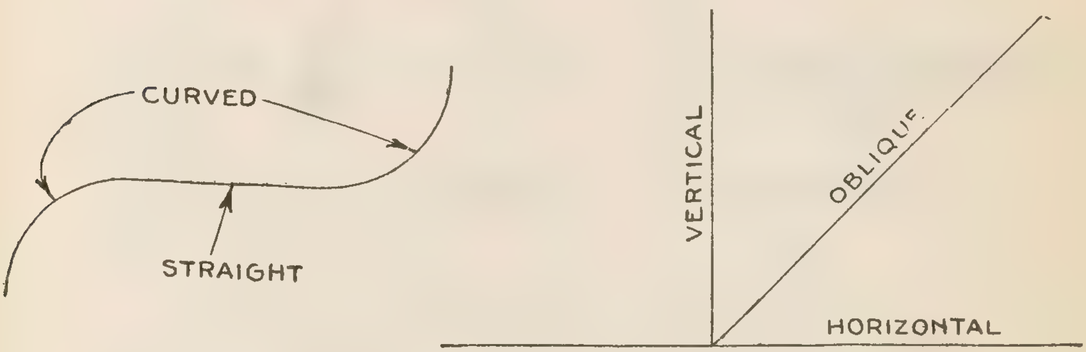
$$\text{Angle L} = \text{angle R}$$
$$\text{Angle A} = \text{angle F}$$

2. *When two lines intersect, any two adjacent angles are equal to two right angles.*

In fig. 9,211.

$$L + A = 180°$$
$$R + F = 180°$$

3. *If a line intersect two parallel lines, the corresponding angles formed by the intersecting line with the parallel lines are equal.*



FIGS. 9,209 and 9,210.—Various lines. 1, mixed; 2, inclined or oblique.

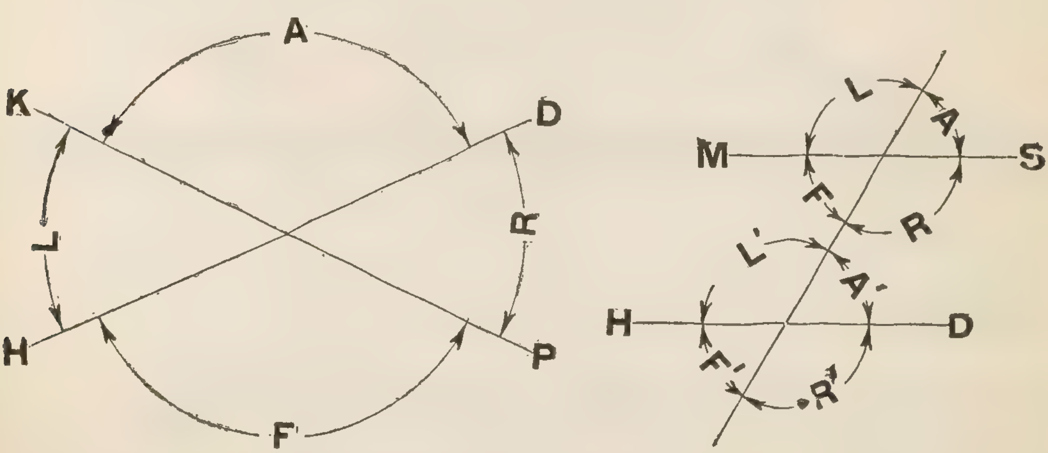
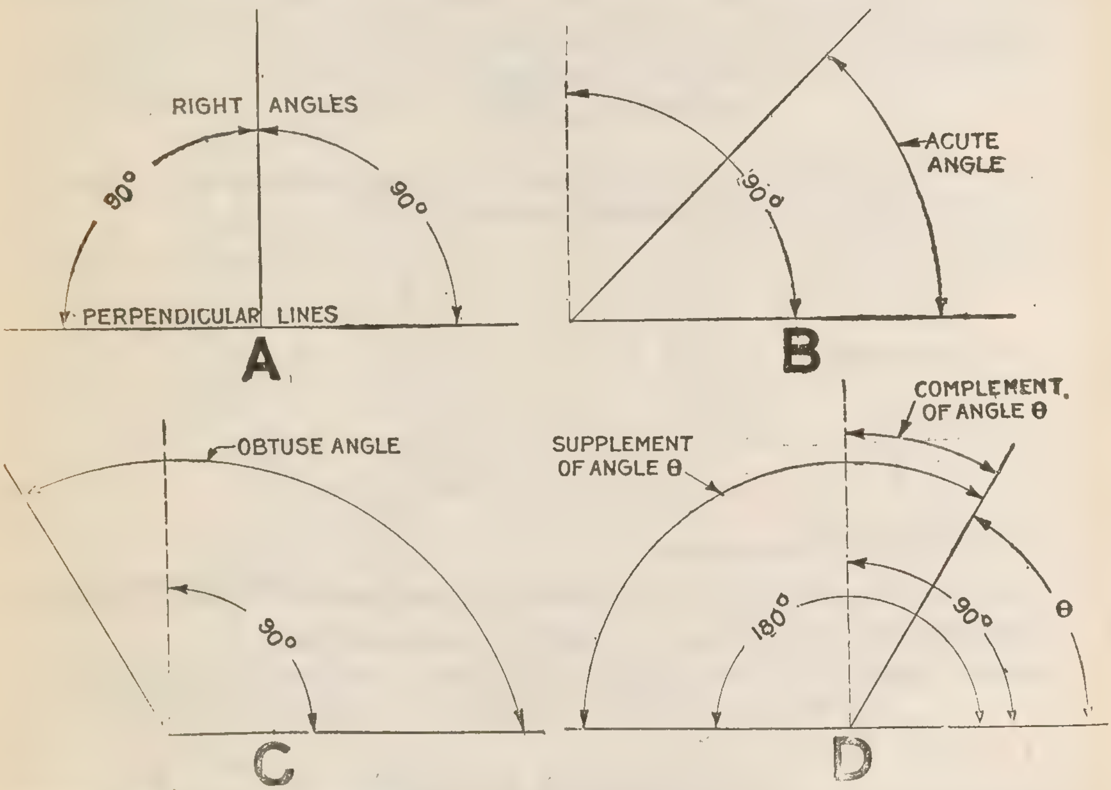


FIG. 9,211 and 9,212.—***Proposition 1, 2 and 3,*** relating to lines.

In fig. 9,212.

$$L = L'; A = A'; R = R'; F = F'$$

Angles.—An angle is *the difference in direction of two lines proceeding from the same point called the vertex.* The lines are called sides and the size of the angle is independent of the length of the lines. With respect to magnitude, angles are classed as:



FIGS. 9,213 to 9,216.—Various angles **A**, right, **B**, acute; **C**, obtuse; **D**, complement and supplement of an angle.

1. Acute
2. Right
3. Obtuse

An acute angle is any angle less than a right angle.

A right angle is formed when one line meets another (not at an extremity) so that two equal angles are formed as in fig. 9,217.

An obtuse angle is an angle greater than a right angle as in fig. 9,215.

The *complement* of an angle is the difference between 90° and the angle; the *supplement* of the angle, the difference between the angle and 180°. These relations are shown in figs. 9,213 to 9,216.

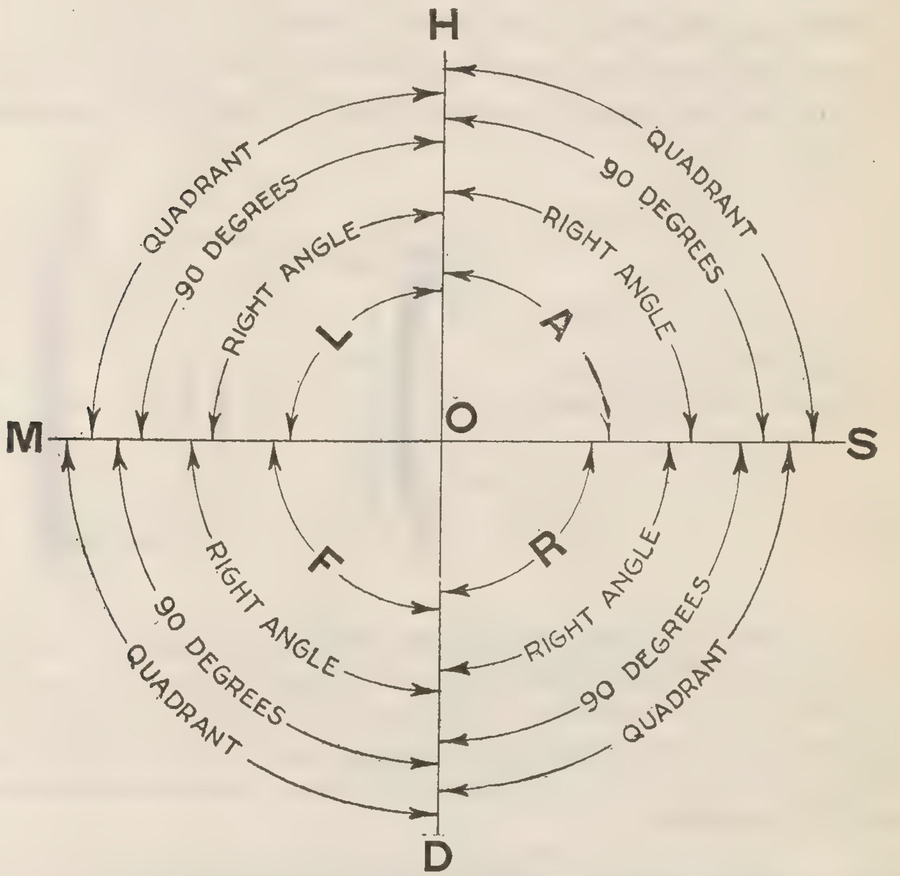


Fig. 9,217.—Four right angles illustrating the measurement of angles. Draw the intersecting lines MS and HD, perpendicular to each other and the four angles formed L,A,R, and F, around the intersection O, are right angles or angles of 90°.

Measurement of Angles.—In fig. 9,217 draw two intersecting lines MS and HD, perpendicular to each other. From the figure it is evident that

1. *The sum of all the angles about a point on one side of a straight line is equal to two right angles.*

That is, L + A = two right angles.
Also R + F = two right angles.

2. *The sum of all the angles about any point is equal to four right angles.*

That is, L + A + R + F = four right angles.

In measuring angles it has been agreed to divide these four angles into 360 equal parts called degrees and indicated by the sign °, thus 360 degrees is written 360°. Since the sum of the four right angles is 360°, each right angle will contain 360° ÷ 4 = 90°. Sometimes these right angles, especially the included arcs, (each of which is one quarter of a circle) are called *quadrants*.*

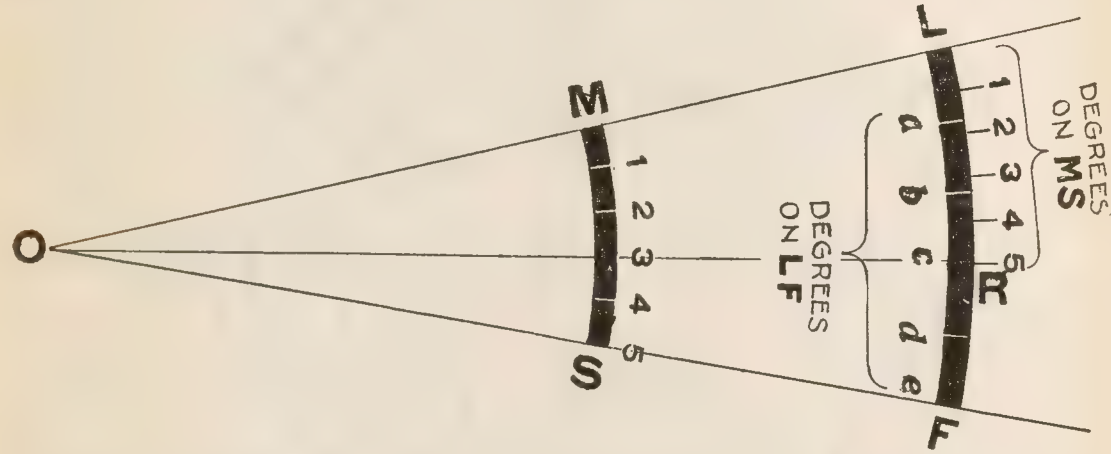


FIG. 9,218.—The length of a degree depends upon the diameter of the circle on which it is measured. Let the angle LOF, be measured on the arc MS, say 5°. Describe with longer radius another arc LF. Lay off on LF, divisions 1,2,3,4,5 same length as 1,2,3,4,5 on MS, giving arc LR, same length as arc MS. Draw radial line OR. Evidently angle LOR is less than angle LOF, hence length of a degree on arc LF, is greater than length of a degree on arc MS. Divide LF, into same number of degrees as MS by points *a,b,c,d,e,* which are the correct degree divisions on arc LF. By inspection, L*a*, for instance is greater than L1, or its equal M1, on arc MS.

*NOTE.—***In steam engineering,** a *quadrant* is a circular shaped bar over which the reversing lever slides. Notches in the quadrant receive the latch on the lever and hold it in any desired position, for regulating the admission of steam to the cylinders. The name is here *incorrectly applied*, as the length of these bars is considerably less than 90°. Also the markings ¼, ⅜, etc. cut off (sometimes stamped on the quadrant) are ***ridiculous*** as these settings do not give the cut offs as marked.

The length of a degree, or the $\frac{1}{360}$ part of a circle depends upon its distance from the center of the circle or apex of the angle as shown in fig. 9,218.

For measuring degrees the draughtsman uses an instrument called a *protractor* as shown in fig. 9,144.

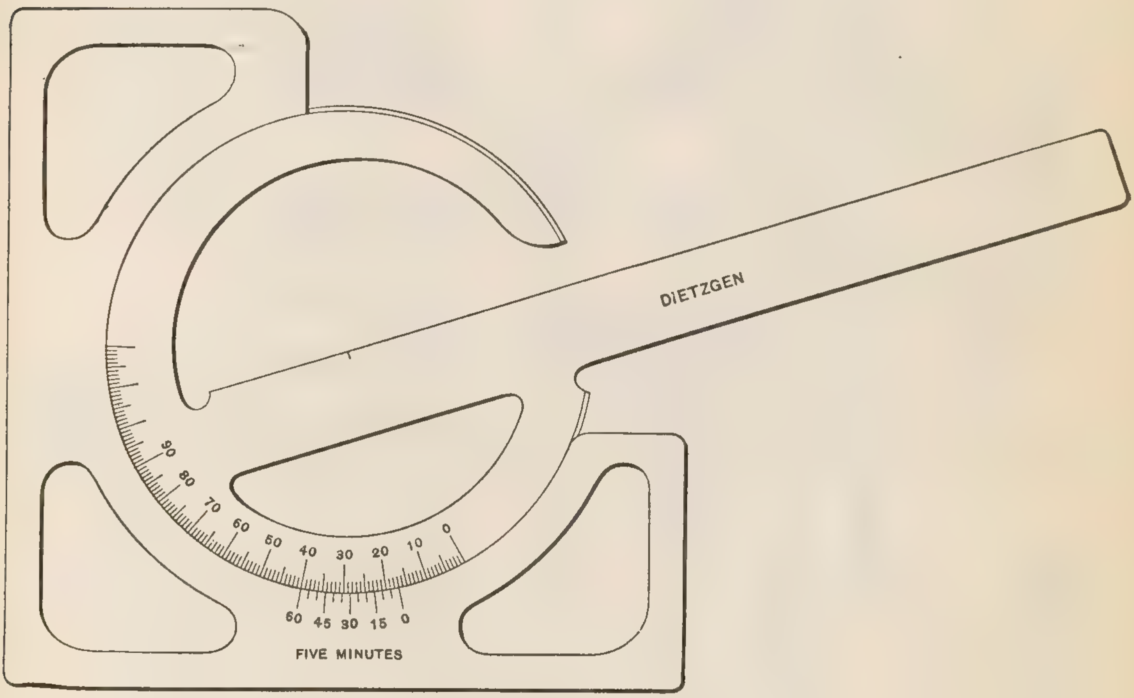
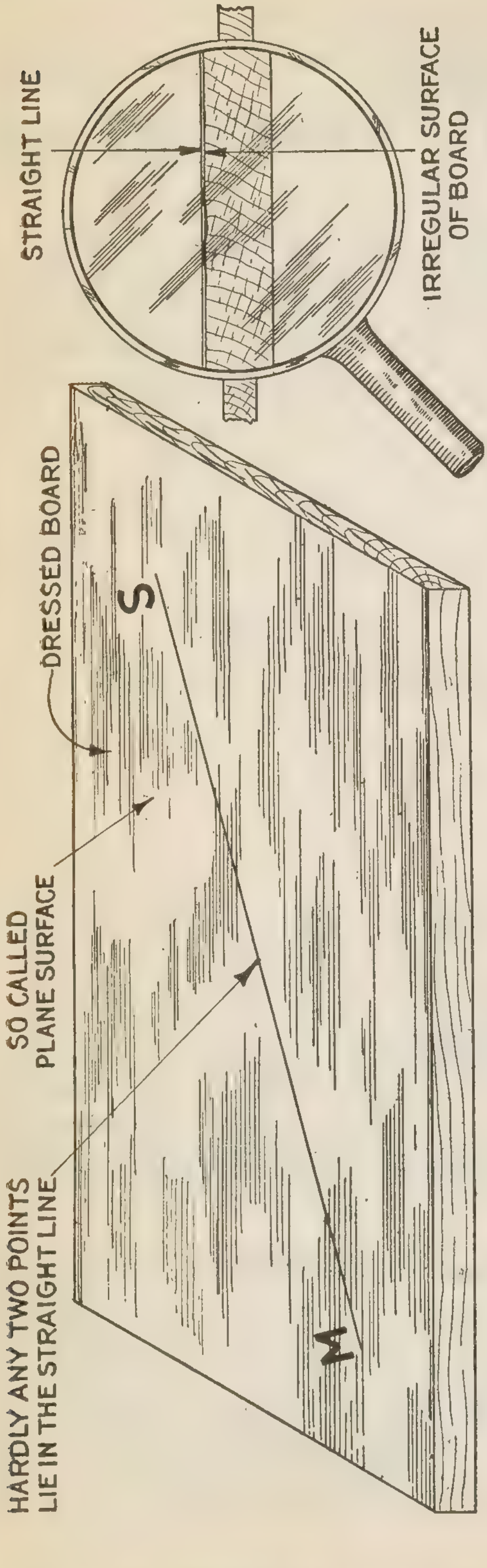


FIG. 9,219.—Dietzgen steel protractor. Blade 8½ ins. long and graduations reading to degrees, with vernier reading to 5 minutes. There are no projections on either face, and therefore it can be used on either edge of the blade or with either side up. This is an advantage when dividing circles, transferring angles, drawing oblique lines at right angles to each other, or laying off given angles each side of a vertical or a horizontal line without changing the setting.

For greater precision in laying out or measuring angles it is sometimes necessary to take a fraction of a degree. Accordingly each degree is divided into 60 equal parts called *minutes* (indicated by ′) and each minute into 60 equal parts called *seconds* (indicated by ″). Thus to represent an angle of 4 degrees 7 minutes and 5 seconds write 4° 7′ 5″.



FIGS. 9,220 and 9,221.—Popular and erroneous conception of a plane or plane surface. The microscopic view, fig. 1,267, indicates that the surface is not plane or flat but is made up of a multiplicity of irregularities so that hardly any two points lie in a straight line joining any two points, as M and S.

Fig. 9,222 shows an arc of one degree divided into minutes. On a protractor such close precision would not be practical as the instrument would be too large. Thus, if each degree occupied an arc 4 ins. long (as in the figure) the circumference of the circle would be $360 \times 4 = 1440$ ins. and its diameter $1440 \div 3.1416 = 458.4$ ins. That is, the radius of the protractor would be $458.4 \div 2 = 279.2$ ins. long. For close reading on a small protractor a vernier scale is used as in fig. 9,219.

Plane Figures.—The term plane figures denotes *a* **plane** *surface bounded by straight or curved lines*. A proper conception of the term "plane" is essential. A plane or plane surface is *one such that any straight line joining any two points lies wholly in the surface.*

Fig. 9,223 defines a plane surface, and figs. 9,220 and 9,221 the ordinary and erroneous idea of such surface. There is a great variety of plane figures, known as *polygons* when their sides are straight lines.

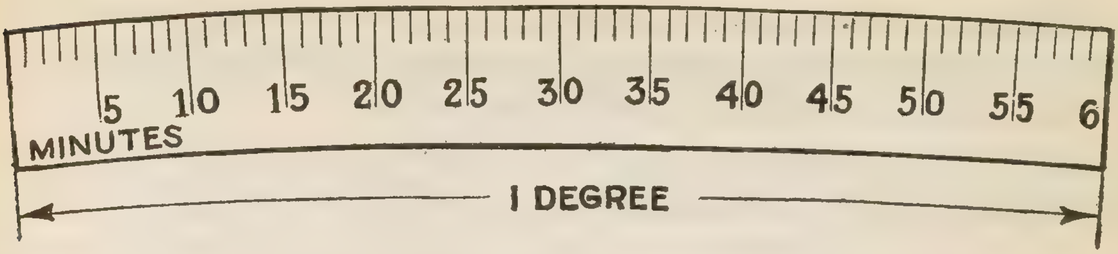


FIG. 9,222.—Protractor scale reading to minutes.

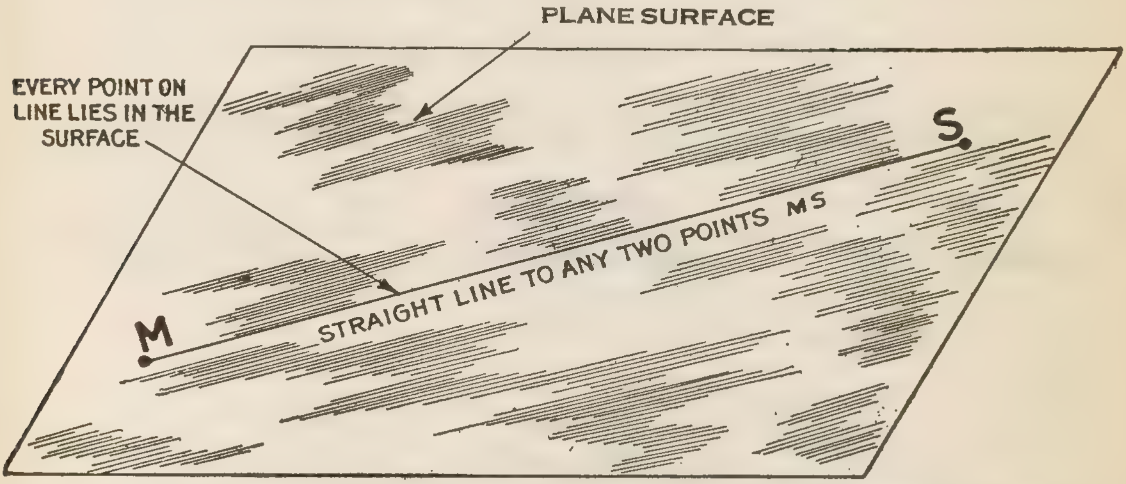


FIG. 9,223.—Proper conception of a "plane" or *plane surface*. A surface such that ***every point on a straight line joining any two points in the surface, lies in the surface.***

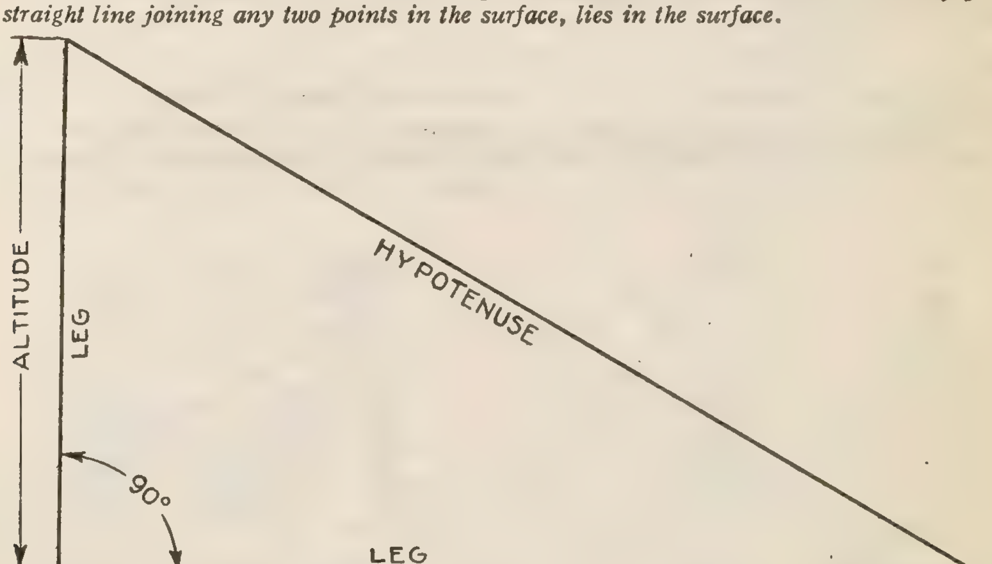
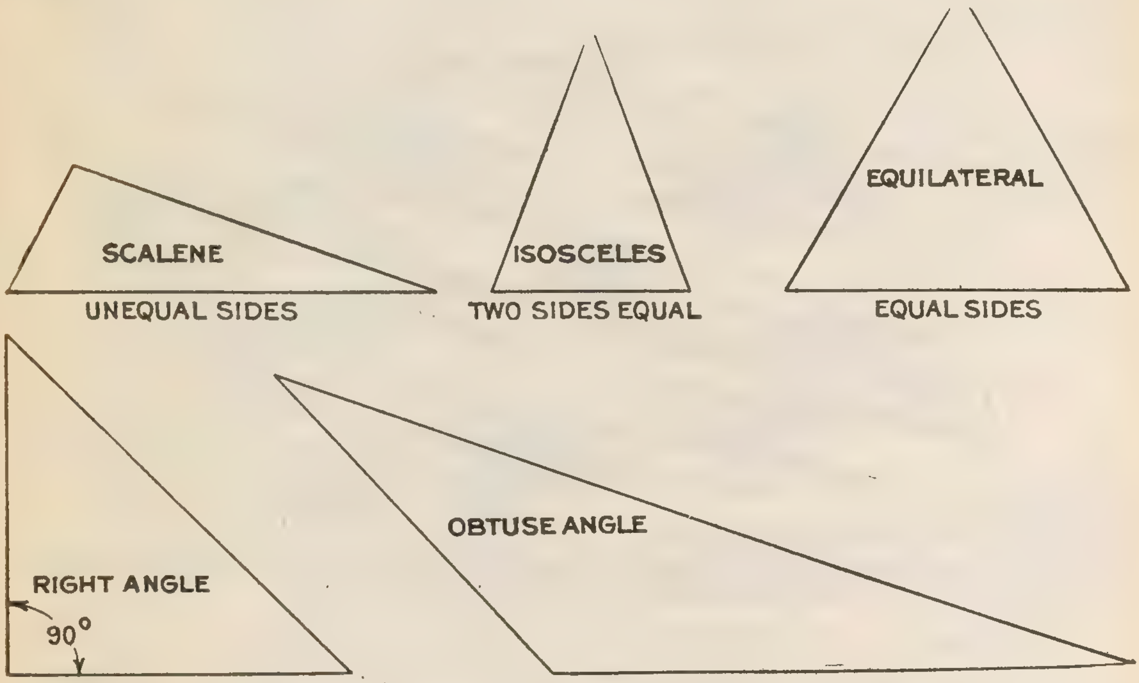


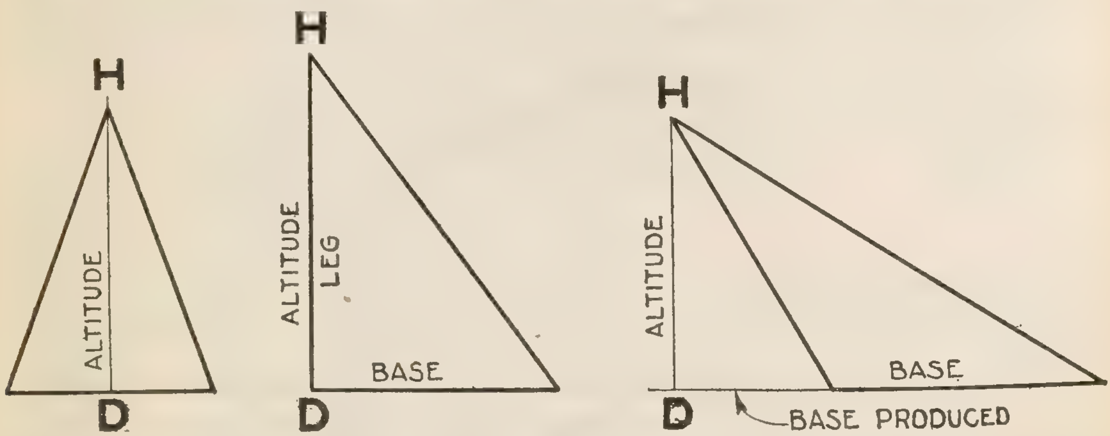
FIG. 9,224.—Right angle triangle illustrating terms the two sides that include the right angle are called the *legs*, the third side or side opposite the right angle, the *hypotenuse*. ***The dimensions*** of a triangle are the *base* and the *altitude*.

Triangles.—*Any surface especially a plane surface, bounded by three straight lines called sides*, is known as a triangle because the junctions of the lines form three angles.

There are numerous kinds of triangles depending on the proportions of the sides as shown in figs. 9,225 to 9,229.



FIGS. 9,225 to 9,229.—Various triangles. A triangle is a polygon having three sides and three angles. By altering the angles and sides a great variety of triangles may be obtained.



FIGS. 9,230 to 9,232.—***Altitude of a triangle.*** The altitude HD, is, in fig. 9,230, the perpendicular distance from the apex H, to the base D; in fig. 9,231, the leg HD perpendicular to the base; in fig. 9,232, the perpendicular distance from the apex H, to base D, produced.

A triangle is called *scalene*, if no two sides be equal; *isosceles*, if two sides be equal; *equilateral*, if all the sides be equal; *acute*, if all the angles be acute; *right angle*, if one angle be a right angle; *obtuse*, if one angle be an obtuse angle.

The *altitude* of a triangle is the perpendicular distance from the vertex to the base, or to the base produced as shown in figs. 9,230 to 9,232. The sum of the lengths of the sides is called the *perimeter*.

Propositions Relating to Triangles

1. *The sum of the three angles in a triangle always equals* 180 *degrees. Hence, if two angles be known, the third angle can always be found.*

In fig. 9,233

$$A + B + C = 180^\circ$$
$$A = 180^\circ - (B + C).$$
$$B = 180^\circ - (A + C).$$
$$C = 180^\circ - (A + B).$$

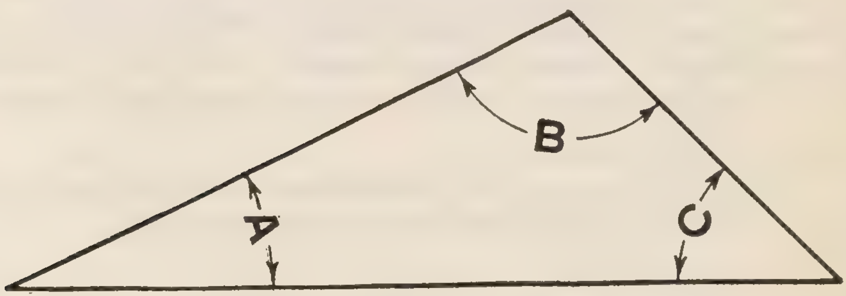
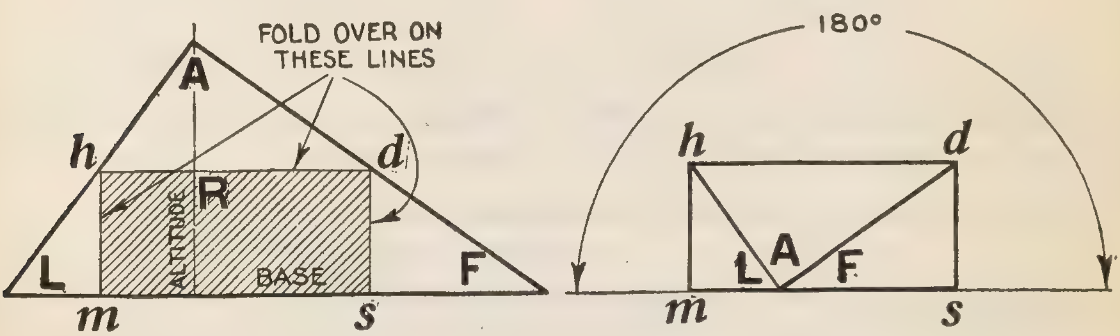


FIG. 9,233.—***Proposition 1,*** relating to triangles.

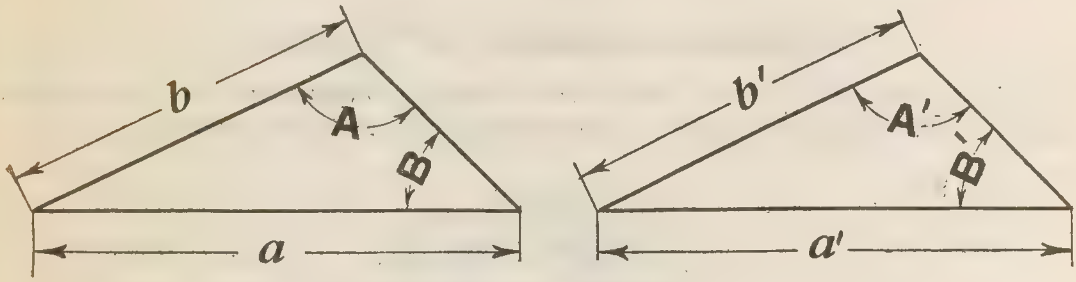


FIGS. 9,234 and 9,235.—Visual proof that *the sum of the three angles of a triangle is equal to two right angles or* 180°. Draw altitude and bisect it at R. Through R, draw *hd*, parallel to base and complete the rectangle *hd, ms*. Cut out the triangle and fold over the ends on the lines *mh, hd* and *ds*, as in fig. 9,235. Evidently the sum of the three angles L, A, and F, thus folded equal two right angles or 180°.

2. *If one side and two angles in one triangle be equal to one side and similarly located angles in another triangle, then the remaining two sides and angle are also equal.*

In figs. 9,236 and 9,237.

If $a = a'$, A = A′ and B = B′, then the two other sides and the remaining angle are also equal.

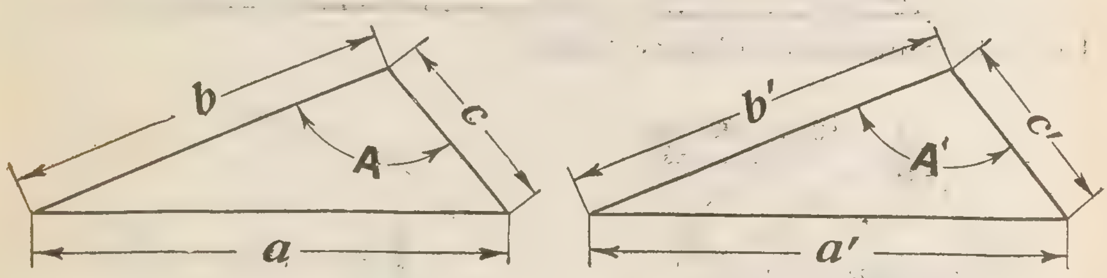


FIGS. 9,236 and 9,237.—***Proposition 2,*** relating to triangles.

3. *If two sides and one angle in one triangle be equal to two sides and a similarly located angle in another triangle, then the remaining side and angles are also equal; provided, however, that the triangles must either be both acute angled triangles, both obtuse angled triangles, or both right angled triangles.*

In figs. 9,238 and 9,239.

If $a = a'$, $b = b'$ and A = A′, then the remaining side and angles are also equal, the triangles in this case being both acute angled.



FIGS. 9,238 and 2,239.—***Propositions 3 and 4,*** relating to triangles.

4. *If the three sides in one triangle be equal to the three sides of another triangle, then the angles in the two triangles are also equal.*

In figs. 9,238 and 9,240.

If $a = a'$, $b = b'$, and $c = c'$, then the angles between the respective sides are also equal.

5. *If the three sides of one triangle be proportional to corresponding sides in another triangle, then the triangles are called similar, and the angles in the one are equal to the angles in the other.*

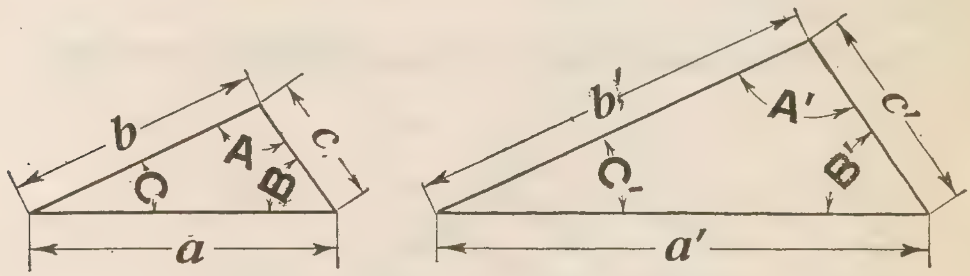
In figs. 9,240 and 9,241.

If $a:b:c = a'b'c'$, then $A = A'$, $B = B'$ and $C = C'$.

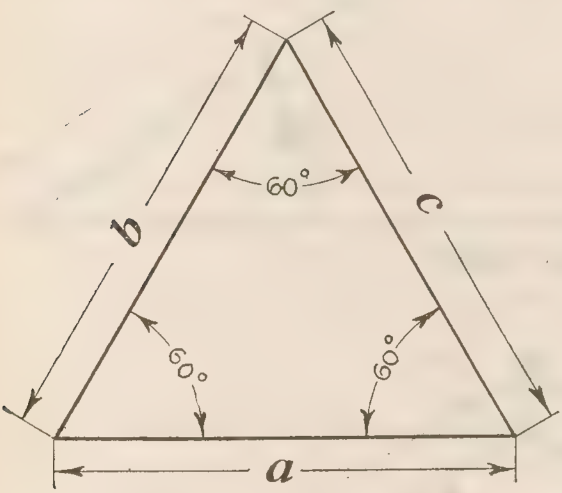
6. *If the angles in one triangle be equal to the angles of another triangle, then the triangles are similar and their corresponding sides are proportional.*

In figs. 9,240 and 9,241.

If $A = A'$, $B = B'$, and $C = C'$ then $a:b:c = a' :b' :c'$.



FIGS. 9,240 and 9,241.—***Propositions 5 and 6,*** relating to triangles.



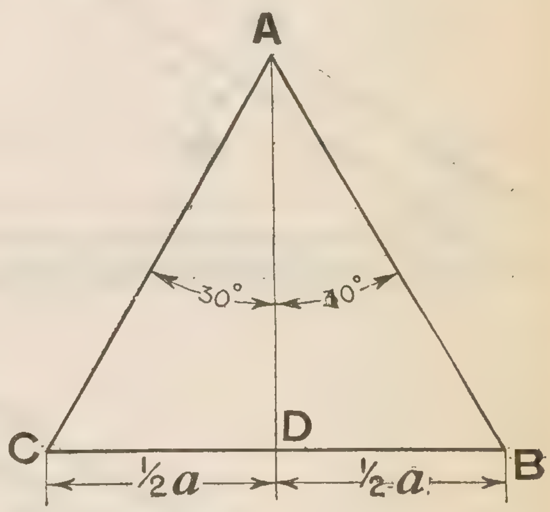


FIG. 9,242.—***Proposition 7,*** relating to triangles.

FIG. 9,243.—***Proposition 8,*** relating to triangles.

7. *If the three sides in a triangle be equal, that is, if the triangle be equilateral, then the three angles are also equal as in fig.* 9,242.

Each of the three equal angles in the equilateral triangle in fig. 9,242 is 60 degrees. If the three angles in a triangle be equal, then the three sides are also equal.

8. *A line which in an equilateral triangle bisects or divides any of the angles into two equal parts, will bisect, also the side opposite the angle and be at right angles to it as shown in fig.* 9,243.

If line AD, divides angle CAB, into two equal parts, it also divides line CB, into two equal parts and is at right angles to it.

9. *If two sides in a triangle be equal—that is, if the triangle be an isosceles triangle, then the angles opposite these sides are also equal.*

In fig. 9,244, if side *b*, equal side *c*, then angle B, equal angle C.

10. *If two angles in a triangle be equal, then the sides opposite these angles are also equal.*

In fig. 9,244, if angles B and C, be equal then side *b* equals side *c*.

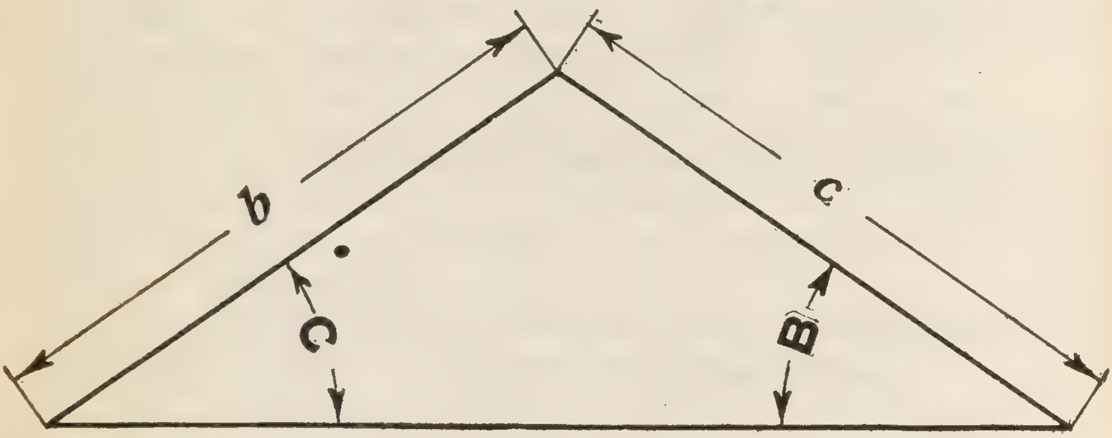


FIG. 9,244.—***Propositions 9 and 10,*** relating to triangles.

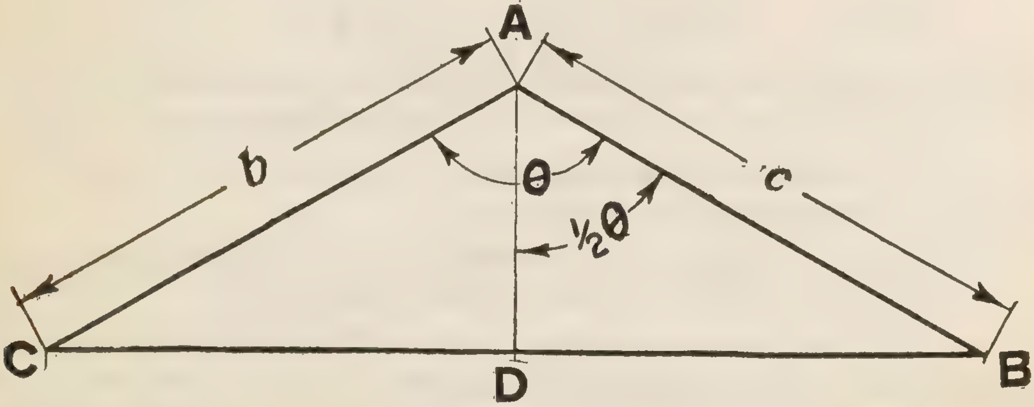


FIG. 9,245.—***Proposition 11,*** relating to triangles.

11. *In an isosceles triangle, if a straight line be drawn from the point where the two equal sides meet, so that it bisects the third side or base of the triangle, then it also bisects the angle between the equal sides and is perpendicular to the base.*

If fig. 9,245.

If $b = c$ and AD bisects CB, then angle CAD = DAB.

12. *In every triangle, that angle is greater which is opposite a longer side. In every triangle, that side is greater which is opposite a greater angle.*

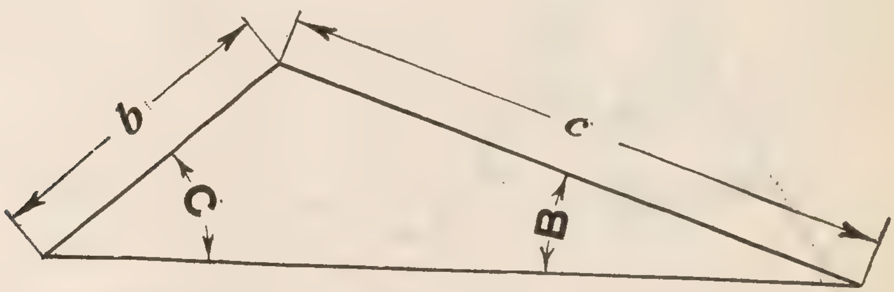


FIG. 9,246.—***Proposition 12,*** relating to triangles.

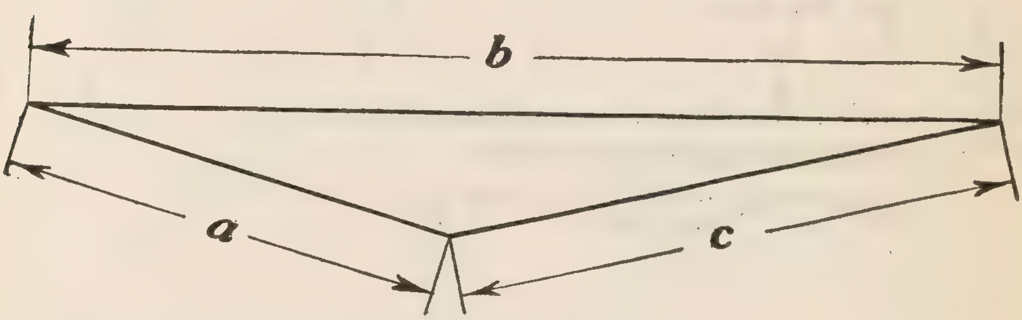


FIG. 9,247.—***Proposition 13,*** relating to triangles.

In fig. 9,246.

If side c, be greater than side b, then angle C, is greater than angle B; also, if angle C, be greater than angle B, then side c, is greater than side b.

13. *In every triangle, the sum of the lengths of two sides is always greater than the length of the third.*

In fig. 9,247.

Side a + side c is always greater than side b.

14. *If one side of a triangle is produced, then the exterior angle is equal to the sum of the two interior opposite angles.*

In fig. 9,248.

Angle D = angle A + angle C. In the case of an equilateral triangle, angle D = 60° + 60° = 120°.

Quadrilaterals.—By definition a *quadrilaterial is any plane*

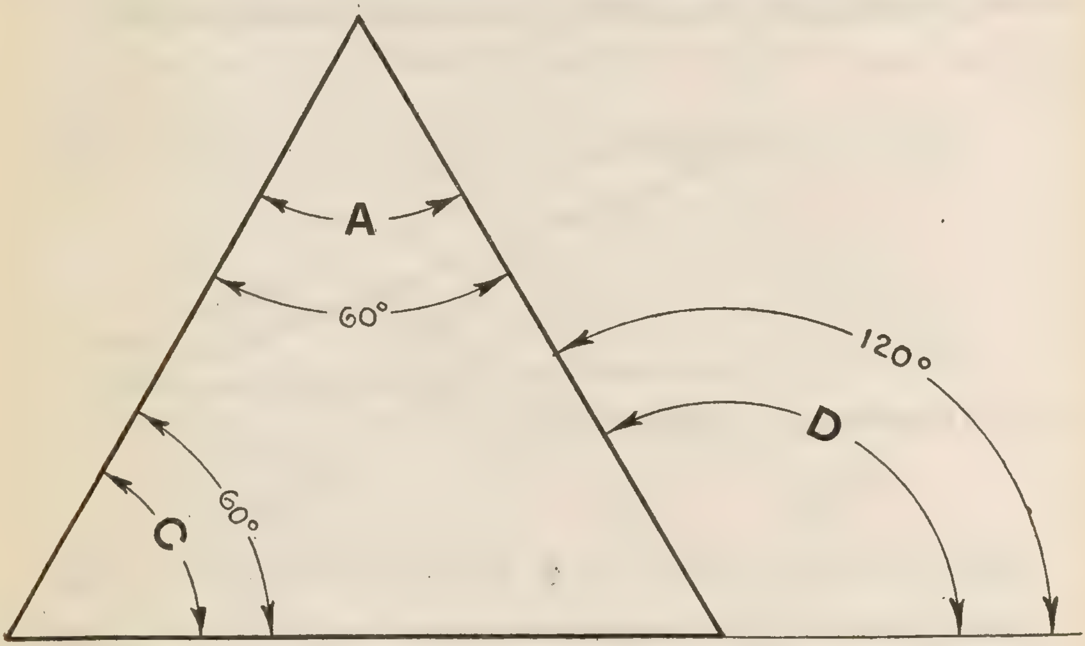


FIG. 9,248.—***Proposition 14,*** relating to triangles.

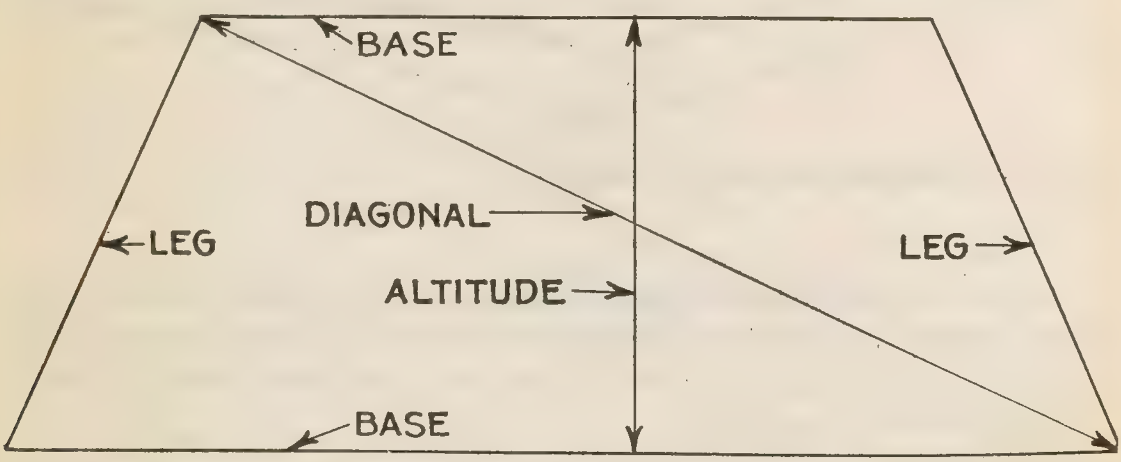
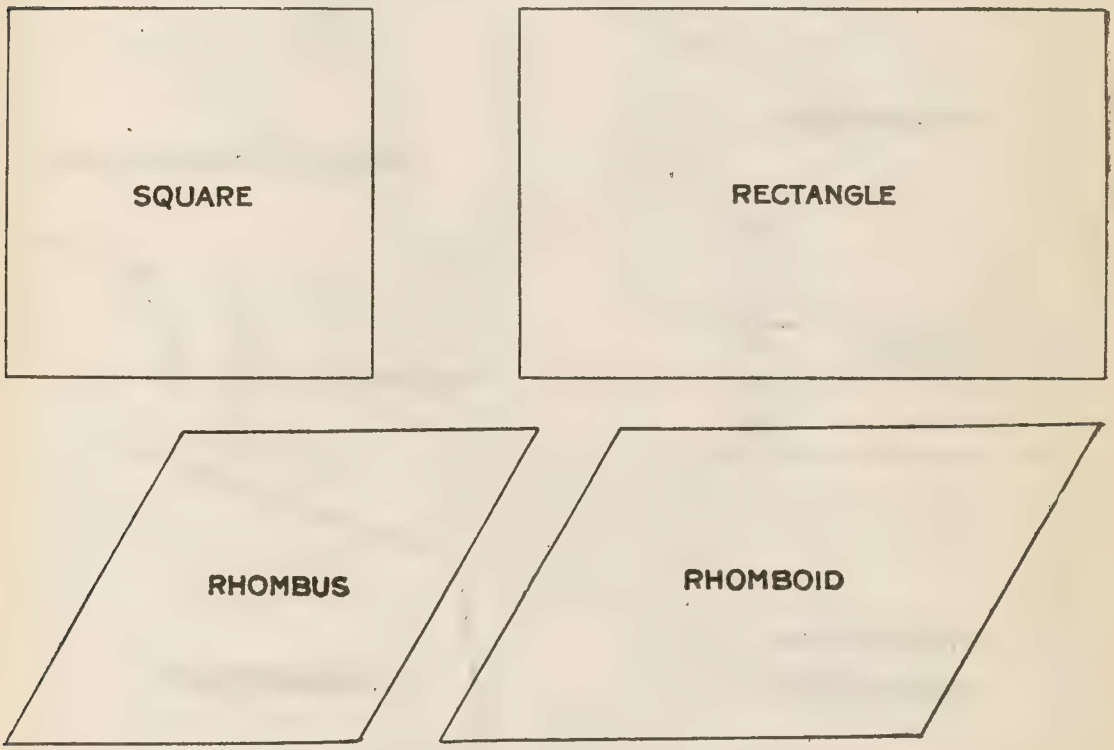


FIG. 9,249.—Quadrilateral illustrating legs, bases, etc. The parallel sides are the *bases;* the distance between the bases, the *altitude*, a line joining two opposite vertices, a *diagonal.*

figure bounded by four straight sides. The terms vertices, sides, angles and perimeter have the same meaning in quadrilaterals as in triangles.

A quadrilateral is called a parallelogram, if the opposite sides be parallel; a trapezoid, if two, and only two, sides be parallel; a trapezium, if no two sides be parallel.

A parallelogram is called a rectangle, if the angles be all right angles; a rhomboid, if the angles be not right angles.



FIGS. 9,250 to 9,253.—Various quadrilaterals I. All sides parallel.

A rectangle is called a square, if the four sides be equal.

A rhomboid is called a rhombus, if the four sides be equal.

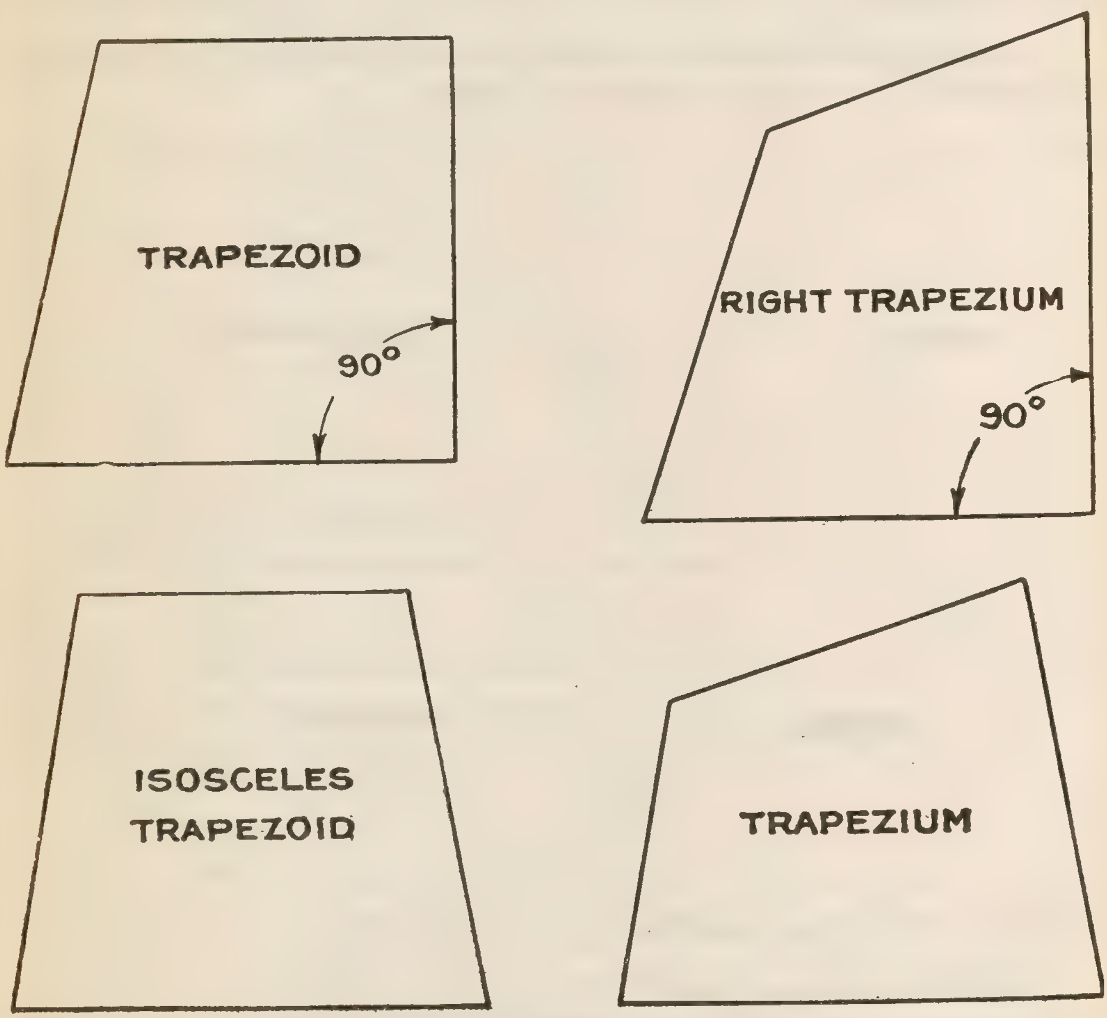
The parallel sides of a trapezoid are called the bases, and the non-parallel sides are called the legs.

A trapezoid is called an isosceles trapezoid if the legs be equal; a right trapezoid, if one leg be perpendicular to the base.

Any side of a parallelogram may be taken as the base. The altitude of a

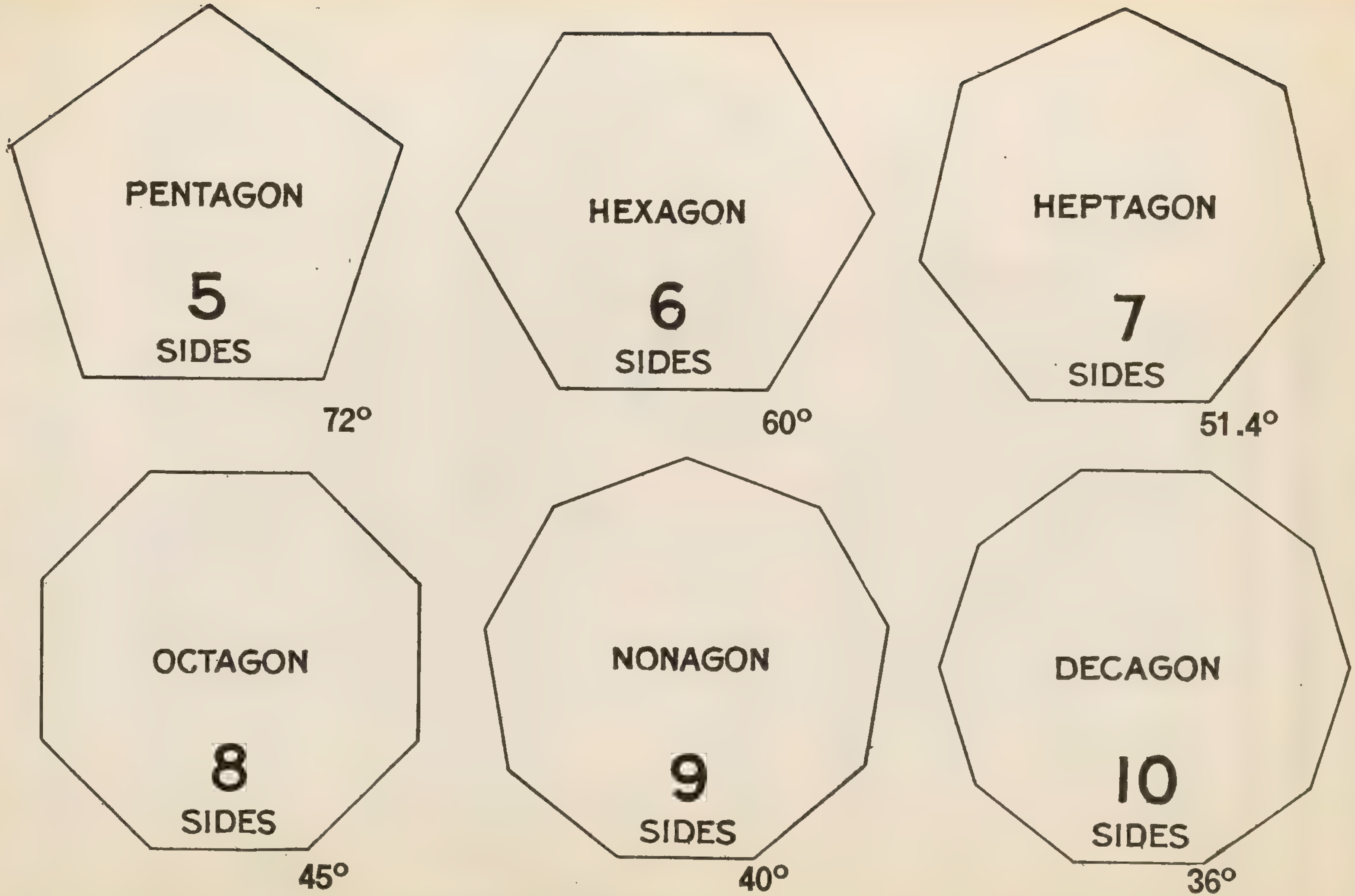
parallelogram is the perpendicular distance from the base to the opposite side.

Figs. 9,250 to 9,257 show various quadrilaterals. A line joining two opposite angles of a quadrilateral is called the



FIGS. 9,254 to 9,257.—Various quadrilaterals II. Trapezoids and trapeziums. A quadrilateral is called a *trapezoid* if two and only two sides be parallel; a *trapezium* if no two sides be parallel; an *isosceles trapezoid*, if the legs be equal; a right trapezoid, if one leg be perpendicular to the base.

diagonal as shown in fig. 9,249, and divides the figures into two triangles.



FIGS. 9,258 to 9,263.—Various polygons having from five to ten sides. Of these the most important are the *hexagon* (six sides, and the *octagon* (eight sides).

Propositions Relating to Quadrilaterals

1. *In any figure having four sides, the sum of the interior angles equals* 360 degrees.

In fig. 9,264

$$L + A + R + F = 360°$$

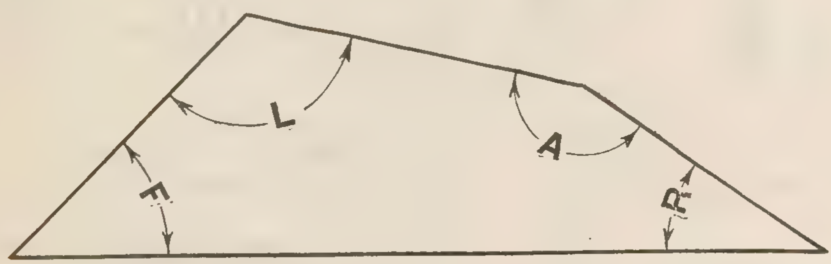
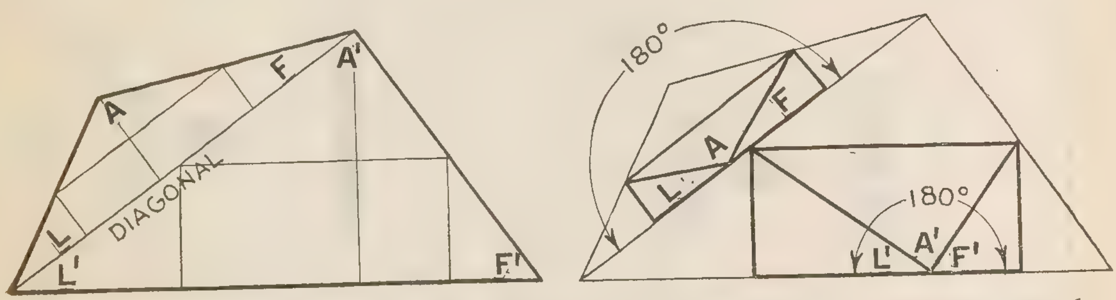
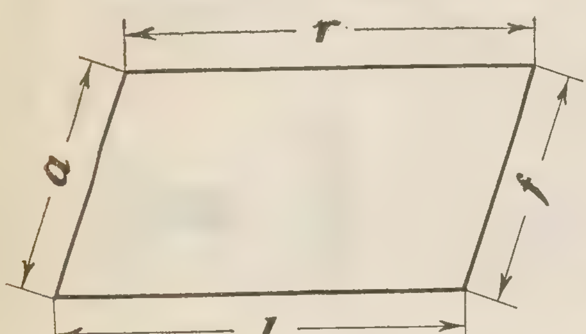


Fig. 9,264.—***Proposition 1,*** relating to quadrilaterals.



Figs. 9,265 and 9,266.—Visual proof that the sum of the angles of a quadrilateral is equal to four right angles or 360°. Draw a diagonal which will divide the figure into two triangles giving the angles L,A,F and L′,A′,F.′ Fold over the angles of each triangle as directed in figs, 9,234 and 9,235 thus obtaining angles L,A,F, = 180° and angles L′,A′,F′, = 180°, a total of four right angles or 360° as in fig. 9,266.



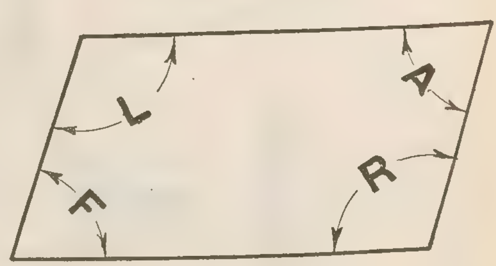


Fig. 9,267.—***Proposition 2,*** relating to quadrilaterals.

Fig. 9,268.—***Proposition 3,*** relating to quadrilaterals.

2. *The sides which are opposite each other in a parallelogram are equal.* In fig. 9,267

$$a = f \text{ and } r = l.$$

3. *The angles which are opposite each other in a parallelogram are equal.* In fig. 9,268

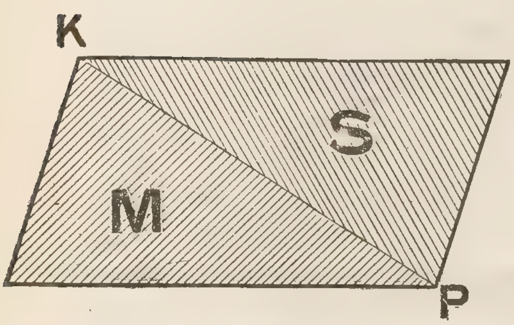
$$A = F \text{ and } L = R.$$

4. *The diagonal divides a parallelogram into two equal parts.* In fig. 9,269

$$\text{triangle M} = \text{triangle S}$$

5. *If two diagonals be drawn in a parallelogram, they bisect each other.* In fig. 9,270

$$HO = OD \text{ and } KO = OP$$



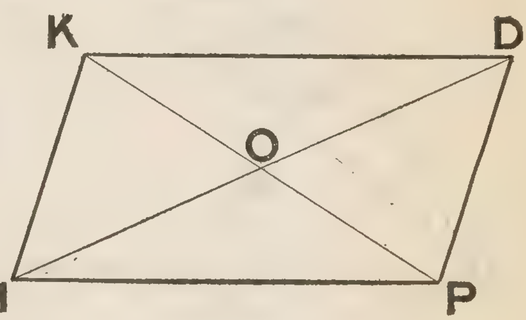


FIG. 9,269.—***Proposition 4,*** relating to quadrilaterals.

FIG. 9,270.—***Proposition 5,*** relating to quadrilaterals.

Polygons.—By definition, a polygon is *a closed figure bounded by straight lines, especially more than four.**

The sides, the perimeter, and the vertices of a polygon are defined as in the case of a triangle. A diagonal of a polygon is a straight line joining two vertices not adjacent.

Polygons have special names corresponding to the number of sides, some of which are given in the following table:

---

*NOTE.—The name polygon is derived from polys, meaning many and gonia, angle; hence, a figure having many angles.

Names of Polygons

Number of sides	5	6	8
Name	pentagon	hexagon	octagon
Number of sides	10	12	20
Name	decagon	dodecagon	isocagon

Propositions Relating to Polygons

1. *By drawing all the diagonals possible from one vertex of a polygon, the number of triangles thus obtained is always two less than the number of sides.*

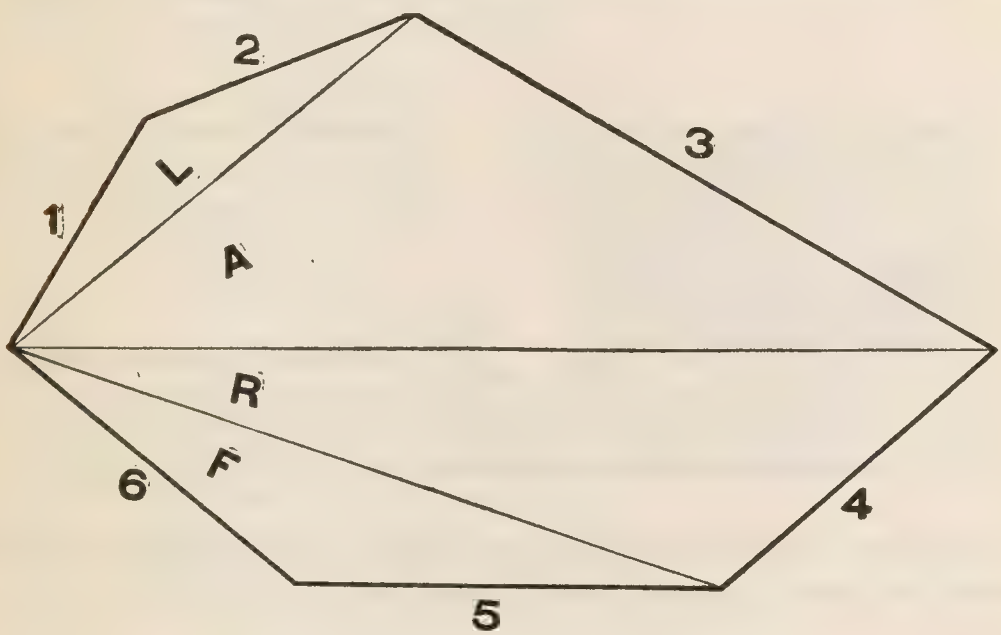


FIG. 9,271.—***Propositions 1 and 2,*** relating to polygons.

In fig. 9,271 there are

$$6 - 2 = 4 \text{ triangles, L,A,R and F.}$$

2. *The sum of the angles of a polygon is equal to* 180° *multiplied by the number of sides minus two.*

In fig. 9,271

$$\text{Sum of angles} = 180° \times (6 - 2) = 720° \text{ or 8 right angles}$$

Regular Polygons.—A regular polygon is a polygon that has all its sides equal and all its angles equal.

The center of a regular polygon is a point equidistant from all the vertices, and also equidistant from all the sides.

Propositions Relating to Regular Polygons

1. *The angles at the center of a regular polygon are equal.*

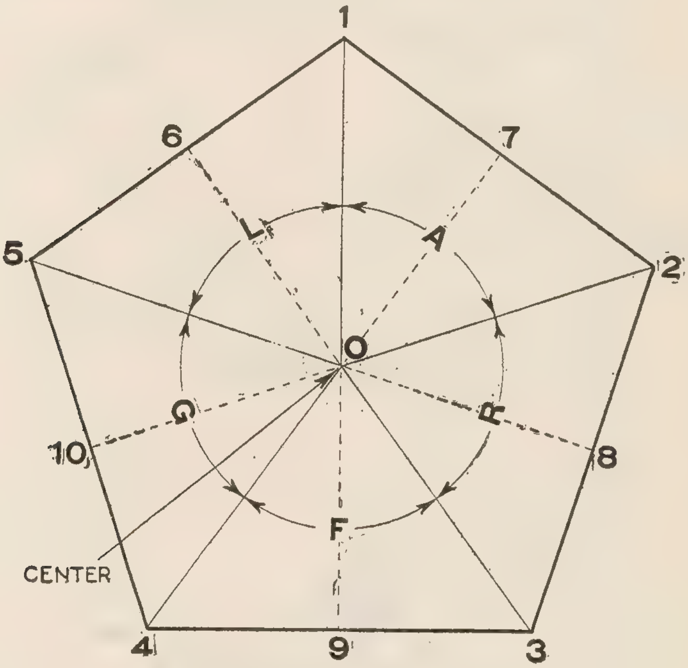


FIG. 9,272.—***Propositions 1, 2 and 3,*** relating to regular polygons.

In fig. 9,272

$$L = A = R = F = G.$$

2. *Straight lines from the center to all the vertices of a regular polygon divide the polygon into as many equal isosceles triangles as there are sides.*

In fig. 9,272, the five lines 01, 02, 03, 04 and 05 divide the polygon into 5 triangles.

3. *Straight lines from the center to all the vertices of a regular polygon and perpendicular to the sides divide the polygon in twice as many right triangles as there are sides of the polygon.*

In fig. 9,272, the lines 01, 02, 03, 04 and 05 and perpendiculars 06, 07, 08, 09 and 010 divide the polygon into $5 \times 2 = 10$ right triangles.

*__Circles.__—A circle is a curved line every point of which is equally distant from a point within called the center.

A diameter of a circle is a straight line drawn through the center, terminating at both ends in the circumference.

A radius of a circle is a straight line joining the center with the circumference. All radii of the same circle are equal and their length is always one half that of the diameter.

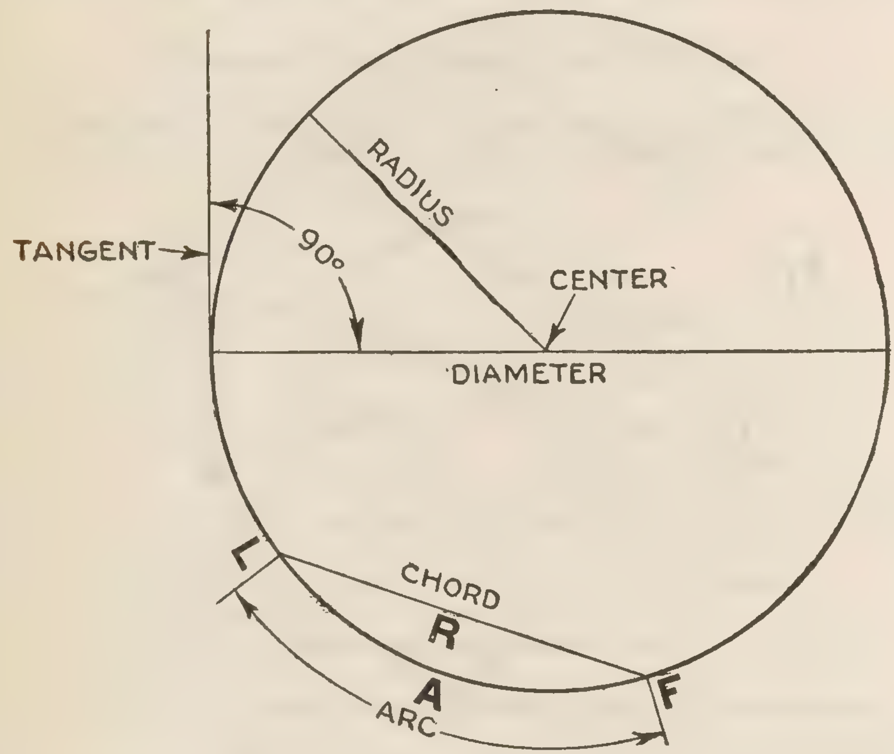


FIG. 9,273.—Circle with names of lines relating to the circle.

An arc is any part of the circumference of a circle. An arc equal to one half the circumference is called a semi-circumference.

A chord is a straight line joining the extremities of an arc. When a number of chords form the sides of a polygon, the polygon is said to be inscribed in the circle.

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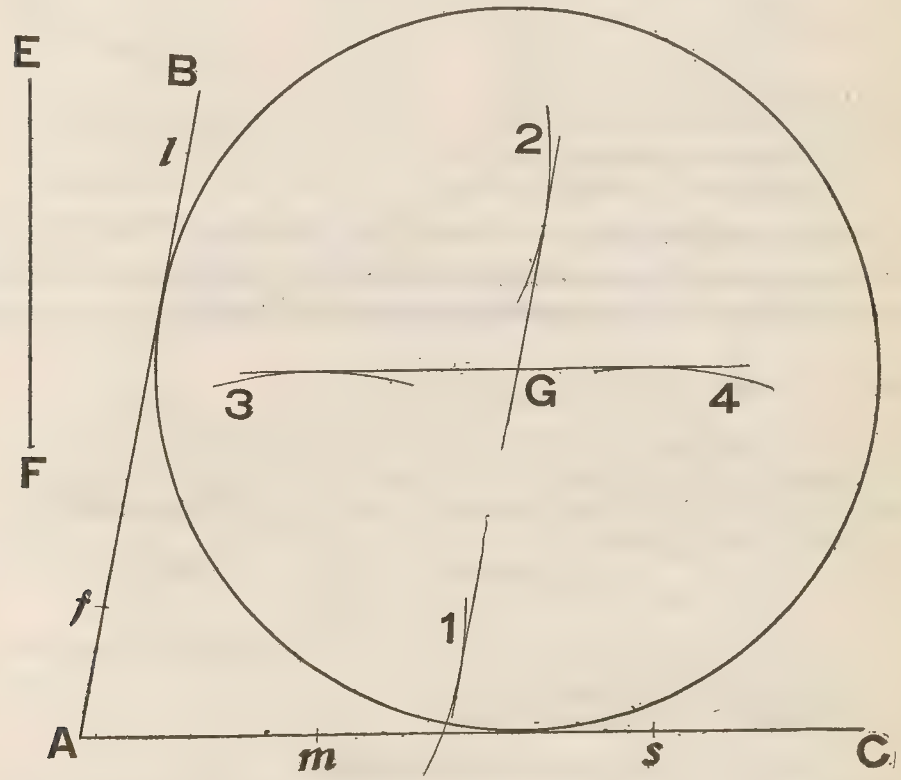
*NOTE.—***Strictly speaking*** the word *circle* means the entire surface of the figure and the boundary curve is the *circumference*. The word circle is, however, frequently intended to mean the circumference as above defined.

A tangent is a straight line which touches the circumference of only one point, called the point of tangency or point of contact.

Concentric circles are circles having the same center.

The circumference of a circle is 3.1416 times longer than its diameter. Thus if the diameter be 2, then circumference $= 3.1416 \times 2 = 6.2832$. The value 3.1416 has been given the name π (Greek letter *pi*.)

Approximation for 3,1416 is $^{22}/_{7}$; thus approximately



FIGS. 9,274 and 9,275.—To describe a circle tangent to two lines A B, forming an angle B A C. With any two points, as L*f*, on A B, as centers and with radius E F, describe arcs 1 and 2. With any two points on A C, as *m s*, as centers and with same radius E F, describe arcs 3 and 4. Draw a tangent to each pair of arcs intersecting at G. A circle described with center G, and radius E F, will be tangent to A B and B C.

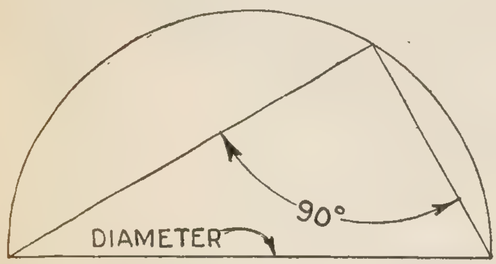
$$\text{Circumference} = \text{diameter} \times \frac{22}{7}$$

$$\text{Diameter} = \text{circumference} \times \frac{7}{22}$$

Propositions Relating to the Circle

1. *An angle inscribed in a semicircle is a right angle.* As in fig. 9,276.

2. *The perpendicular to a radius at its extremity is a tangent to the circle.* As in fig. 9,277.



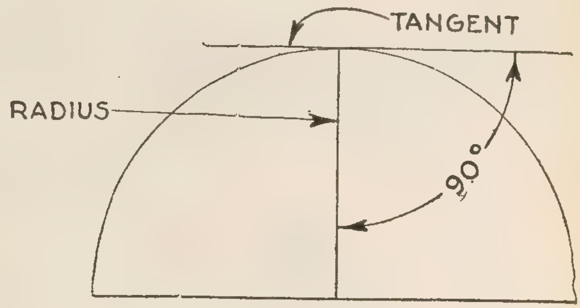
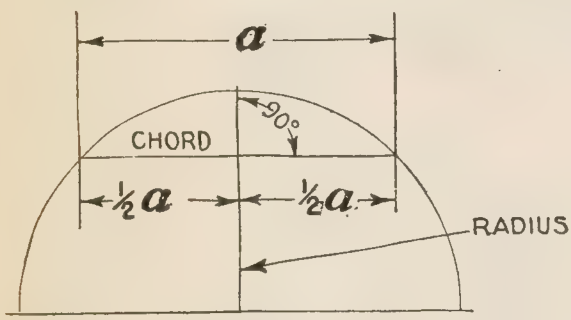


FIG. 9,276.—***Proposition 1,*** relating to circles.
FIG. 9,277.—***Proposition 2,*** relating to circles.

3. *A radius perpendicular to a chord bisects the chord.* As in fig. 9,278.

4. *Two tangents from an exterior point make equal angles with the straight lines which joins the exterior point to the center of the circle.* As in fig. 9,279.



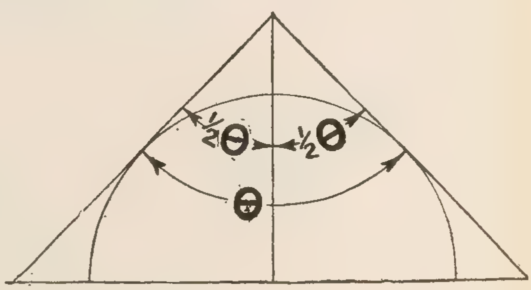
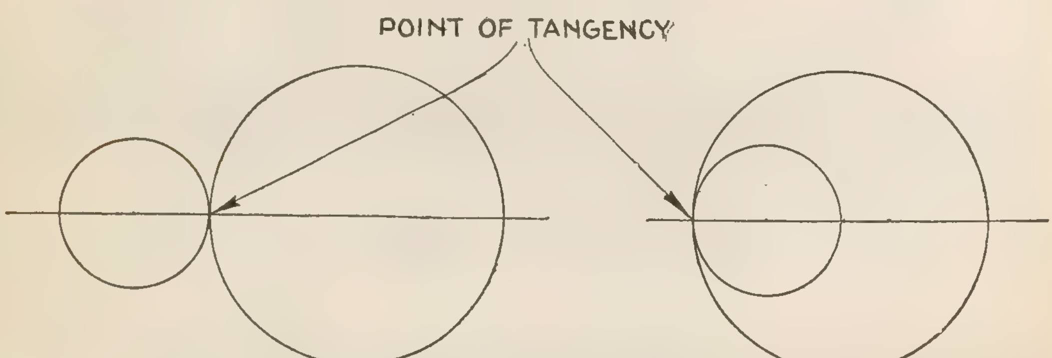


FIG. 9,278.—***Proposition 3,*** relating to circles.
FIG. 9,279.—***Proposition 4,*** relating to circles.



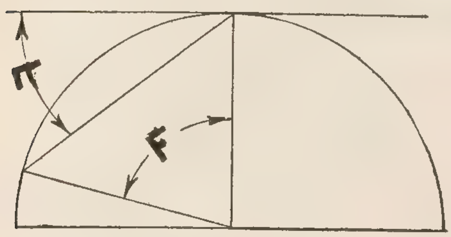
FIGS. 9,280 and 9,281.—***Proposition 5,*** relating to circles.

5. *If two circles be tangent to each other then the straight line which passes through the centers of the two circles must also pass through the point of tangency.* As in figs. 9,280 and 9,281.

6. *The angle between a tangent and a chord drawn from the point of tangency equals one half the angle at the center subtended by the chord.*

In fig. 9,282

Angle L = ½ angle F.



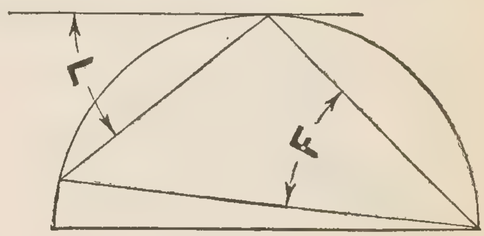


Fig. 9,282.—***Proposition 6,*** relating to circles.
Fig. 9,283.—***Proposition 7,*** relating to circles.

7. *The angle between a tangent and a chord drawn from the point of tangency equals the angle at the periphery subtended by the chord.*

In fig. 9,283

Angle L = angle F.

8. *If an angle at the circumference of a circle, between two chords, be subtended by the same arc as the angle at the center between two radii, then the angle at the circumference is equal to one half of the angle at the center.*

In fig. 9,284

L = ½ F.

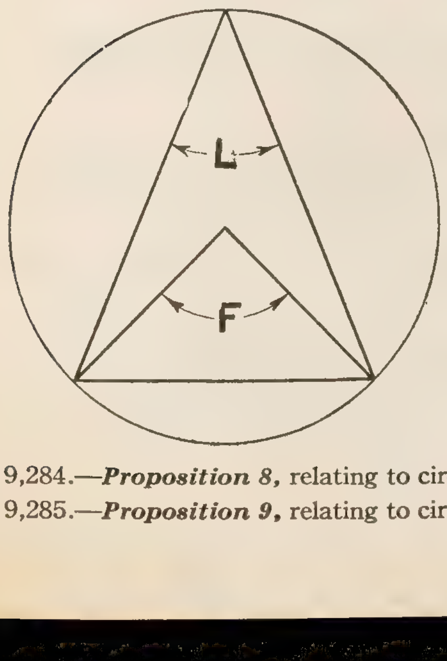


Fig. 9,284.—***Proposition 8,*** relating to circles.
Fig. 9,285.—***Proposition 9,*** relating to circles.

9. *All angles having their vertices at the periphery of a circle and subtended by the same chord are equal.*

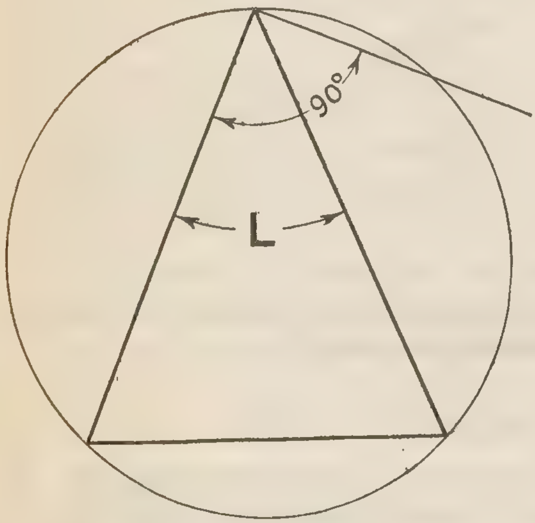
In fig. 9,285.

$$L = A = R = F.$$

10. *An angle subtended by a chord in a circular segment larger than one half the circle is an acute angle—an angle less than* 90 *degrees.*

In fig. 9,286

Angle L is *less* than 90°.



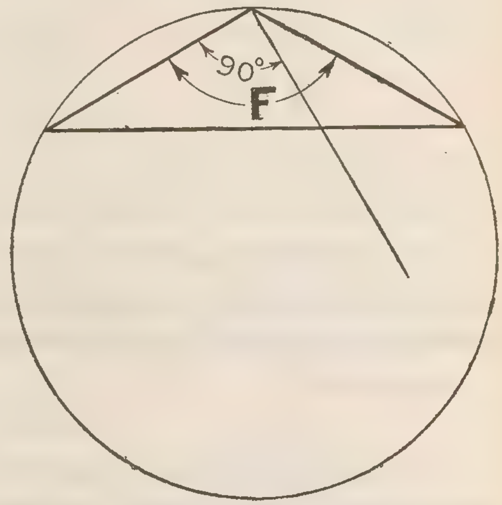
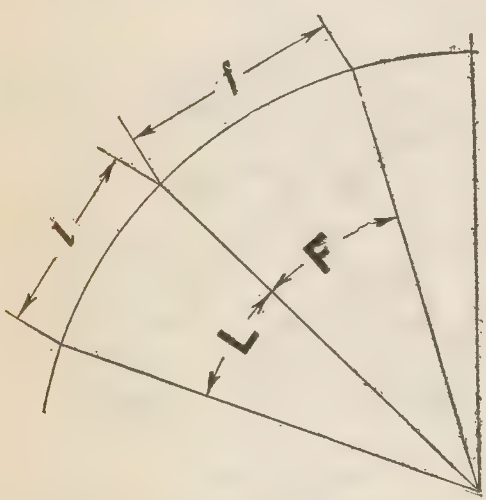


FIG. 9,286.—***Proposition 10,*** relating to circles.
FIG. 9,287.—***Proposition 11,*** relating to circles.



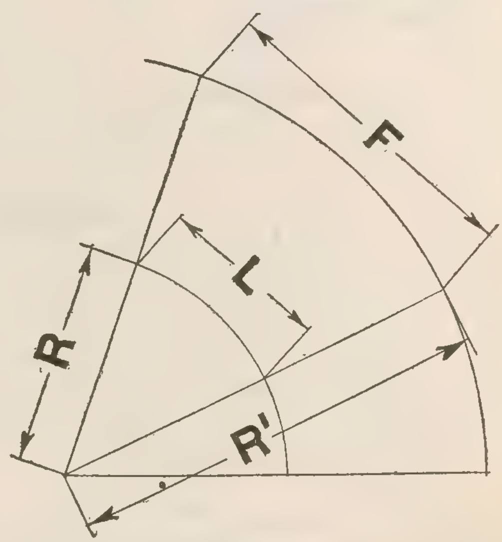


FIG. 9,288.—***Proposition 12,*** relating to circles.
FIG. 9,289.—***Proposition 13,*** relating to circles.

11. *An angle subtended by a chord in a circular segment less than one half the circle is an obtuse angle, that is, an angle greater than 90 degrees.*

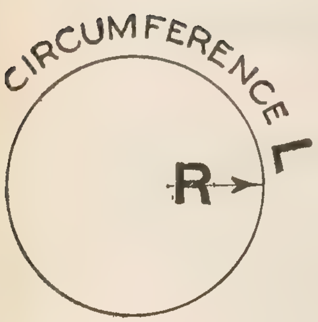
In fig. 9,287

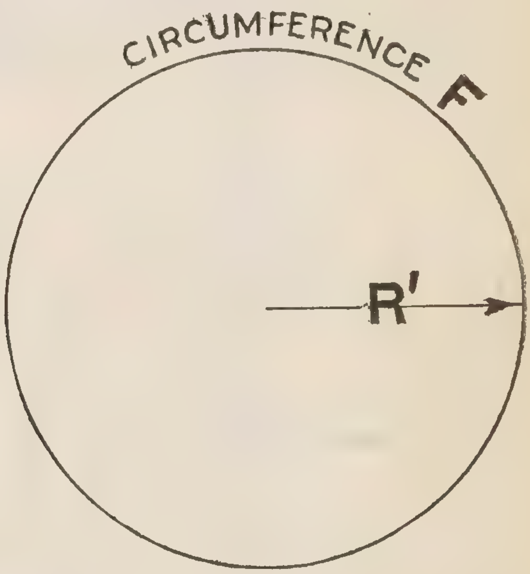
Angle F is *greater* than 90°.

12. *The length of circular arcs of the same circle are proportional to the corresponding angles at the center.*

In fig. 9,288

$$L : F = l : f.$$





Figs. 9,290 and 9,291.—***Proposition 14,*** **relating to circles.**

13. *The length of circular arcs having the same center angle are proportional to the length of the radii.*

In fig. 9,289

$$L : F = R : R'.$$

14. *The circumferences of two circles are proportional to their radii.*

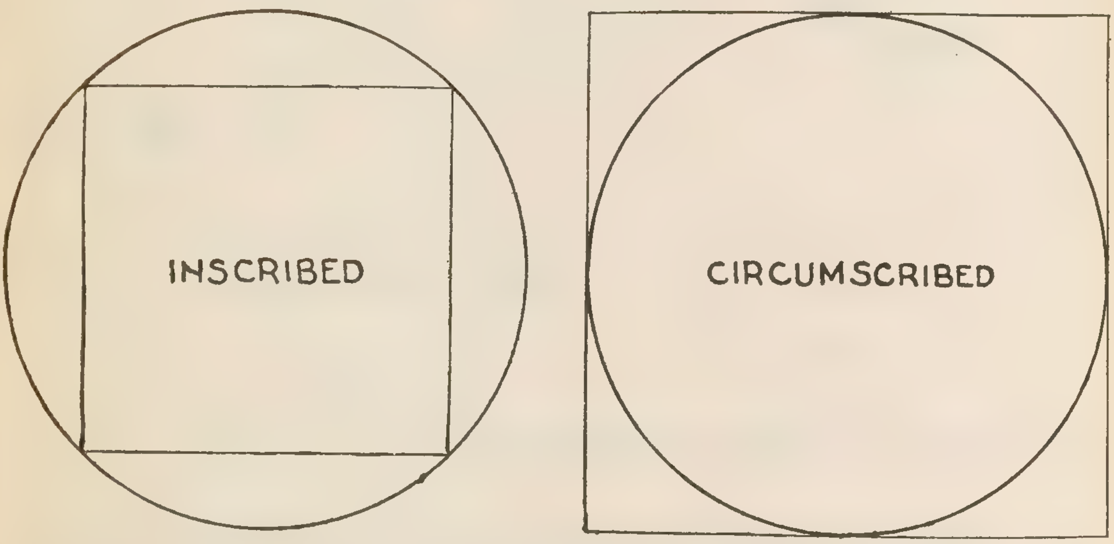
In figs. 9,290 and 9,291.

$$L : F = R : R'.$$

Relation of the Circle
to its
Equal, Inscribed, and Circumscribed Squares

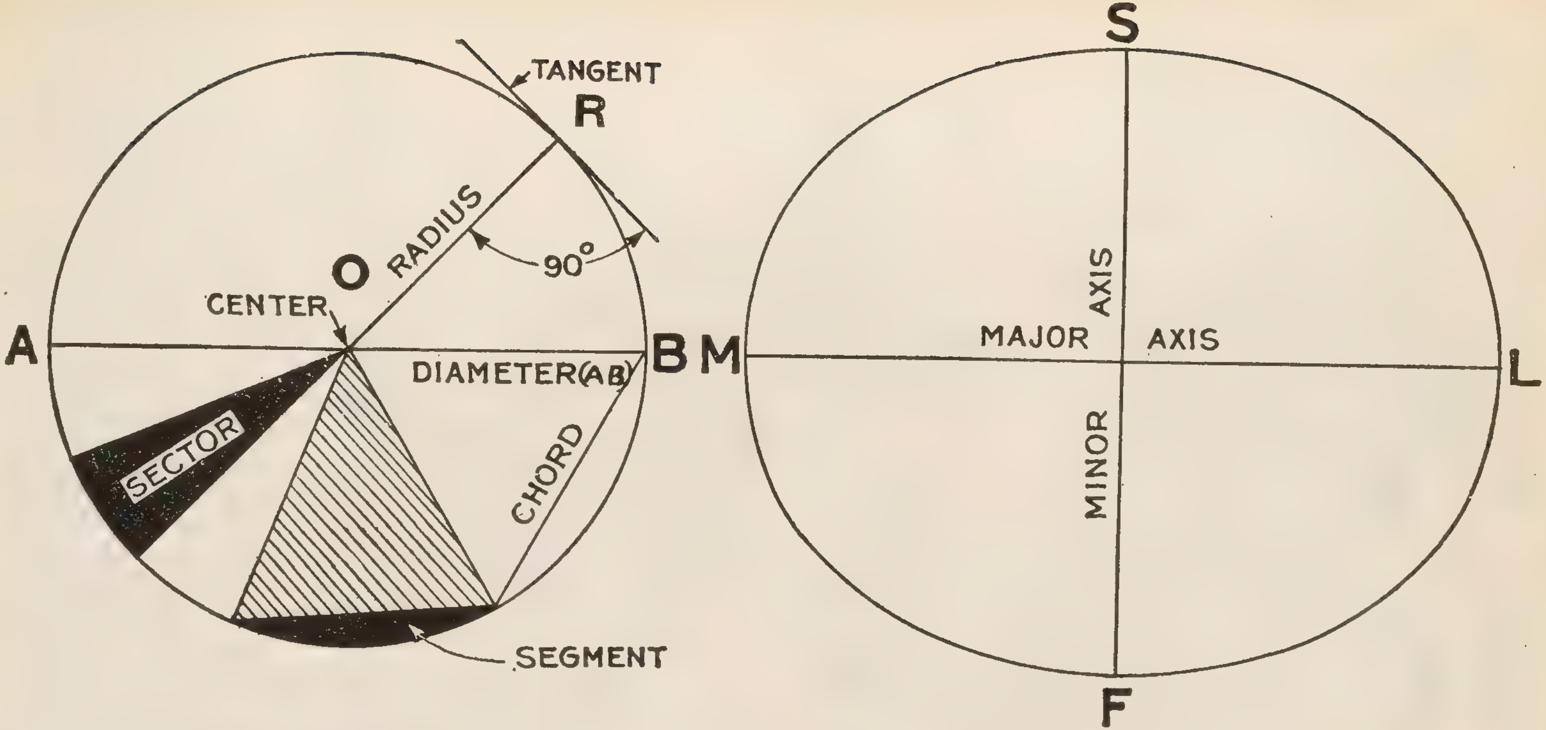
(According to Kent.)

Diameter of circle	×	.88623	= side of equal square.
Circumference of circle	×	.28209	= side of equal square.
Circumference of circle	×	1.1284	= perimeter of equal square.
Diameter of circle	×	.7071	= side of inscribed square.
Circumference of circle	×	.22508	= side of inscribed square.
Area of circle × .90031	÷	diameter	
Area of circle ×		1.2732	= area of circumscribed square.



FIGS. 9,292 and 9,298.—Inscribed and circumscribed squares.

Area of circle ×	.63662	= area of inscribed square.
Side of square ×	1.4142	= diam. of circumscribed circle.
Side of square ×	4.4428	= circum. of circumscribed circle.
Side of square ×	1.1284	= diam. of equal circle.
Side of square ×	3.5449	= circum. of equal circle.
Perimeter of square ×	.88623	= circum. of equal circle.
Square inches ×	1.2732	= circular inches.

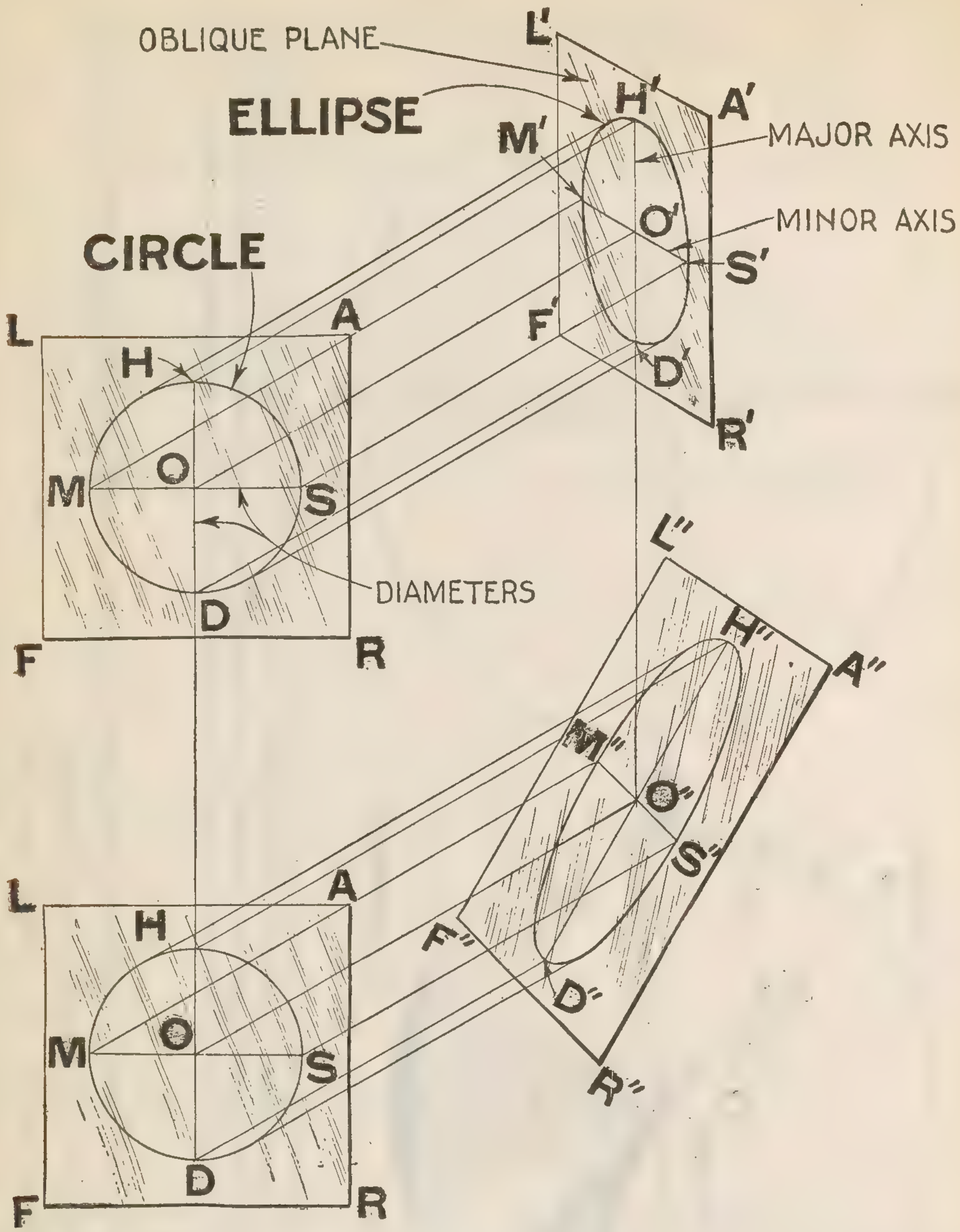


FIGS. 9,294 and 9,295.—Curved figures. Fig. 9,294, circle; fig. 9,295, ellipse. ***A circle*** is a plane figure bounded by a uniformly curved line, every point of which is equidistant from a point O, within called the center. OR, is a radius and AB, a diameter. The figure also illustrates a sector, segment, and chord. ***An ellipse*** is a curved figure enclosed by a curved line which is such that the sum of the distances between any point on the circumference and the two foci is invariable. ML, major axis; SF, minor axis.

Ellipse.—An ellipse is *a plane curve such that the sum of the distances from any point of the curve to two fixed points is a constant.*

The two fixed points are called the *foci*.

The longest diameter of the ellipse is called the *major axis*, and the shortest



FIGS. 9,296 and 2,297.—Pictorial definition of an ellipse. Fig. 9,296, one axis of ellipse parallel to a diameter of the circle; fig. 9,297 no axis of ellipse parallel to diameter of the circle. Points on the ellipse are obtained by projecting points from the circle over to the oblique plane. Thus, in fig. 9,296, points as M,H,S and D are projected over to the oblique plane by lines MM′, HH′, SS′ and DD′, parallel to the center line OO′, cutting the oblique plane in points M′,H′,S′, and D′. A curve drawn through these points will be *an ellipse or the projection of the circle on the oblique plane.*

diameter the *minor axis*. The major and minor axes bisect each other at right angles in a point called the center.

An ellipse may be defined as *the projection of a circle in a plane oblique to the plane of the circle.*

The plane of projection may be so inclined that an axis of the ellipse is

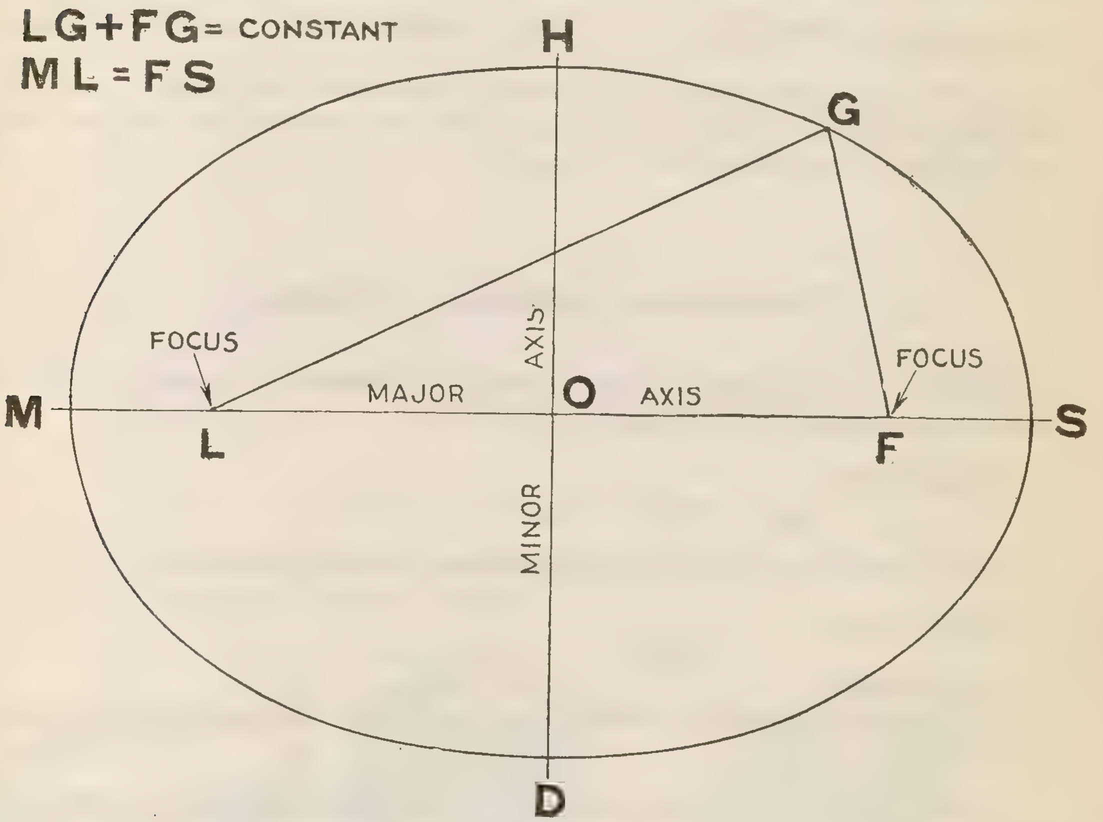


Fig. 9,298.—Ellipse. MS, major axis; LF, minor axis. L and F are the *foci* and G any point on the curve. An ellipse is defined by the equation LG and FG = constant.

parallel to a diameter of the circle, as in fig. 9,296, or so inclined that neither axis of the ellipse is parallel to a diameter of the circle as in fig. 9,297.

Any line drawn through the center and terminated by the curve at each extremity is a diameter.

Conjugal diameters of an ellipse are two diameters so related that the tangents at the ends of either are parallel to the other.

Ellipses can be drawn in infinite variety, as to length and width. The major and minor axes may have any imaginable difference in length. They can never be equal, but the nearer they are to each other in length, the closer does the ellipse approach the form of a circle. Only one elliptic curve belongs to any two given major and minor axes. By holding a penny, first in nearly a vertical position, and then gradually turning it round until hardly any of the surface is visible, the circular edge of the coin presents every conceivable change in the form of an ellipse.

No portion of the curve of an ellipse coincides with an arc of a circle.

An ellipse is often inaccurately called an oval, but the latter is a distinct curvilineal figure, something like an ellipse, but broader at one end than at the other, like the shape of an egg.

Propositions Relating to Ellipses

1. *The foci are at equal distances from the extremities of the major axis, and are also equidistant from the center of the ellipse.*

In fig. 9,298

$$ML = FS \text{ and } OL = OF.$$

2. *The positions of the foci depend upon the ratio of the axes.*

In fig. 9,298

$$ML : LO = HO : MO.$$

3. *The major and minor axes of an ellipse divide the figure into four similar parts.*

4. *The sum of the lengths of lines from the foci to any point on the curve is a constant.*

In fig. 9,298

$$LG + FG = \text{constant}.$$

5. *The sum of the lengths of the lines joining the foci to any point on the curve equal length of major axis.*

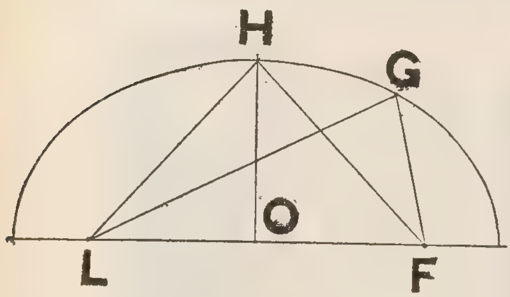
In fig. 9,298

$$LG + GF = MS.$$

6. *A normal to the curve at any point bisects the angle formed by lines from the foci to that point.*

In fig. 9,300, normal NR bisects angle θ formed by lines LG and FG, from foci L and F, to point G.

Solids.—These have three dimensions: length, breadth, and thickness. The bounding planes are called the *faces* and their intersections *edges*. A *prism* is a solid whose ends are equal and parallel polygons and its sides, parallelograms. The *altitude* of a prism is the perpendicular distance between its opposite



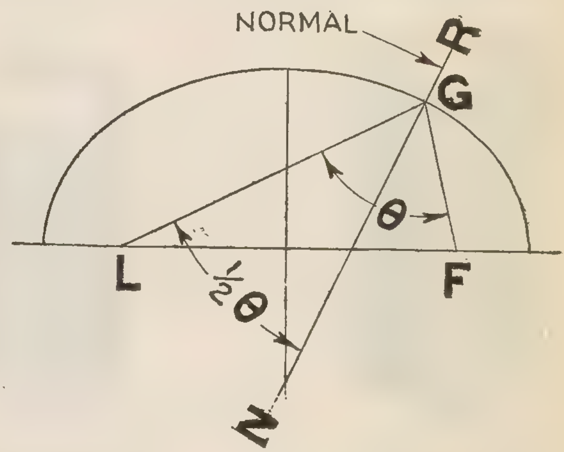


Fig. 9,299.—***Proposition 6,*** relating to ellipses.

Fig. 9,300.—***Proposition 7,*** relating to ellipses.

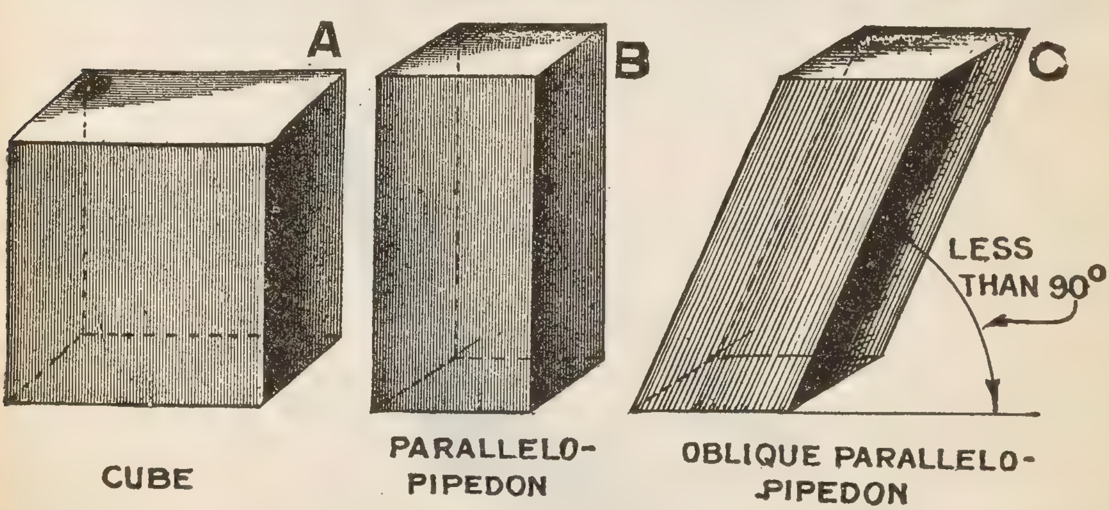
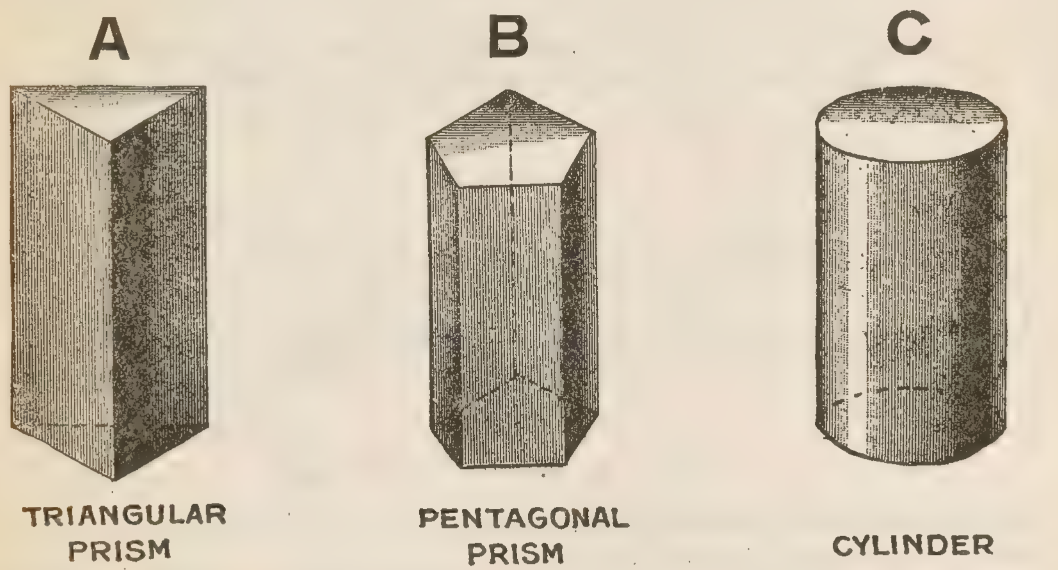


Fig. 9,301 to 9,303.—Various prisms **I.** **A,** cube, or equilateral parallelopipedon; **B,** parallelopidedon; **C,** oblique parallelopipedon.

sides. A *parallelopipedon* is a prism bounded by six parallelograms, the opposite ones being parallel and equal. A *cube* is a parallelopipedon whose faces are equal. An important solid is the cylinder or body bounded by a uniformly curved surface and having its ends equal and parallel circles. There are numerous other solids having curved surfaces such as cones, spheres, etc.



FIGS. 9,304 to 9,306.—Various solids II. **A,** triangular prism; **B,** pentagonal prism; **C,** cylinder.

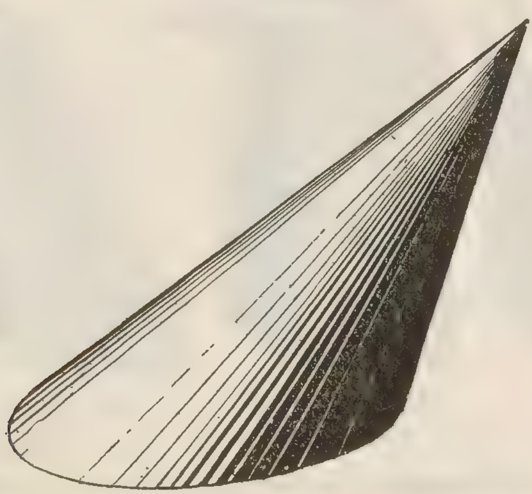


FIG. 9,307.—Scalene cone.

CHAPTER 144

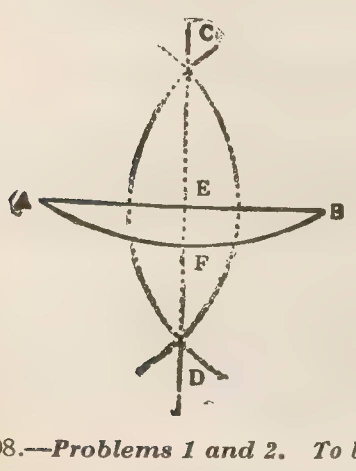
Geometrical Problems

Geometrical Problems.—The following problems illustrating how various geometrical figures are constructed, are to be solved by the use of pencil, dividers, compasses, and scale.

Many of these problems are such as are encountered in sheet metal in laying out patterns, and accordingly proficiency in the solution of such problems will be of value to turners and sheet metal workers.

Problem 1.*—To bisect or divide into two equal parts a straight line or arc of a circle.*

In fig. 9,308, from the ends AB, as centers, describe arcs cutting each other at C and D, and draw CD, which cuts the line at E, or the arc at F.



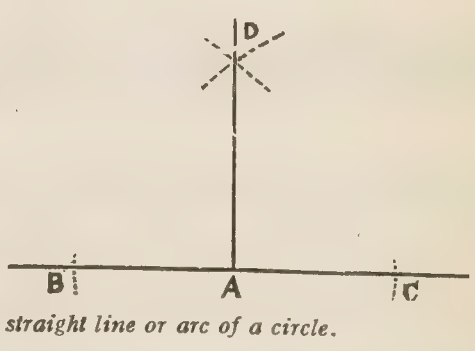


FIG. 9,308.—***Problems 1 and 2.*** *To bisect a straight line or arc of a circle.*

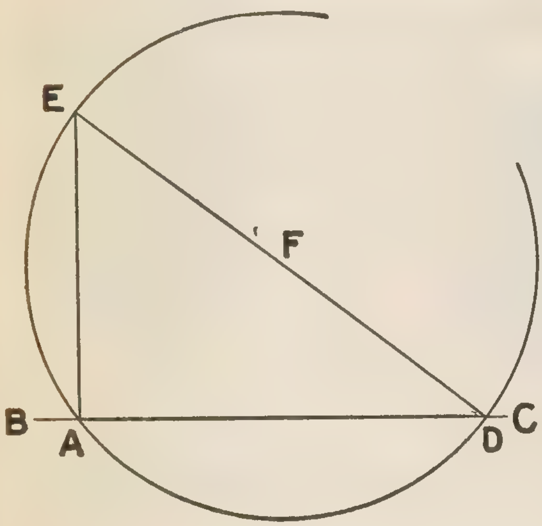
FIG. 9,309.—***Problem 3*** *To erect a perpendicular to a straight line, from a given point in that line.*

***Problem 2.**—To draw a perpendicular to a straight line, or a radial line to an arc.*

In fig. 9,308, the line CD, is perpendicular to AB, moreover, the line CD, is radial to the arc AFB.

***Problem 3.**—To erect a perpendicular to a straight line, from a given point in that line.*

In fig. 9,309 with any radius from any given point A, in the line BC, describe arcs cutting the line at B and C. Next, with a longer radius describe arcs with B and C, as centers, intersecting at D, and draw the perpendicular DA.



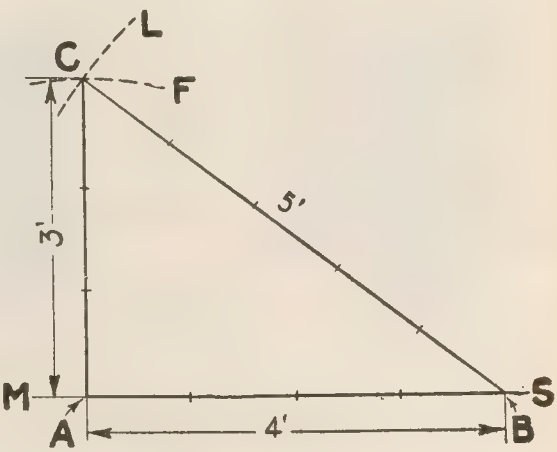


FIG. 9,310.—***Problem 3.*** Second method.

FIG. 9,311.—***Problem 3.*** Third method (boat builder's laying down method).

Second method. In fig. 9,310, from any center F, above BC, describe a circle passing through the given point A, and cutting the given line at D; draw DF, and produce it to cut the circle at E; now draw the perpendicular AE.

Third method (boat builders' laying down method).—In fig. 9,311 let MS be the given line and A, the given point. From A, measure off a distance AB, say 4 ft. With centers A and B, and radii of 3 and 5 ft. respectively, describe arcs F and L, intersecting at C. Draw a line through A and C, which will be the perpendicular required.

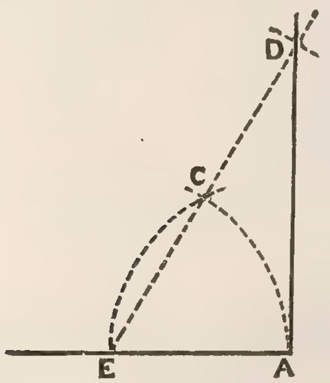
Fourth method.—In fig. 9,312, from A, describe an arc EC, and from E, with the same radius, the arc AC, cutting the other at C; through C, draw

a line ECD, and set off CD, equal to CE, and through D, draw the perpendicular AD.

Problem 4.—*To erect a perpendicular to a straight line from any point without the line.*

In fig. 9,313, from the point A, with a sufficient radius, cut the given line at F and G; and from these points describe arcs cutting at E. Place triangle on points A and E, and from A, draw perpendicular to line GF.

Second method.—In fig. 9,314, from any two points B,C, at some distance apart, on the given line, and with the radii BA, CA, respectively, describe arcs cutting at A and D. Place triangle on points A and D, and draw the perpendicular AD.



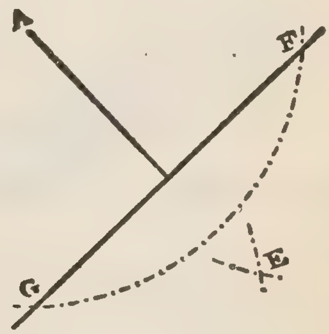
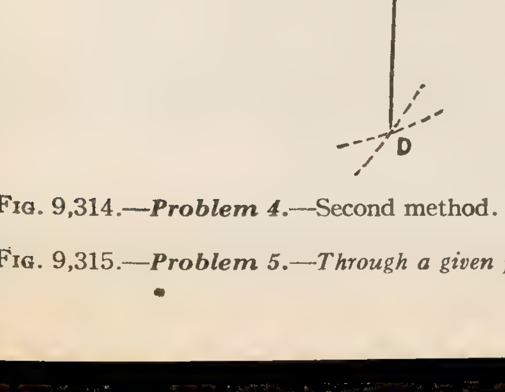


FIG. 9,312.—***Problem 3.*** Fourth method.

FIG. 9,313.—***Problem 4.*** *To erect a perpendicular to a straight line from any point without the line.* If there be no room below the line, the intersection may be taken above the line, that is to say, between the line and the given point.



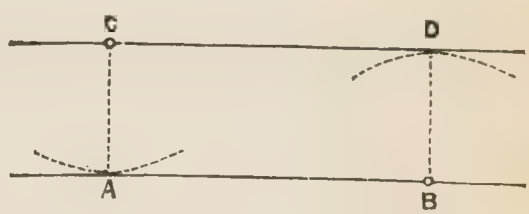


FIG. 9,314.—***Problem 4.***—Second method.

FIG. 9,315.—***Problem 5.***—*Through a given point to draw a line parallel to a given line.*

Problem 5.*—Through a given point to draw a line parallel to a given line.*

In fig. 9,315, with C, as center describe an arc tangent to the given line AB; the radius will then equal distance from given point to the given line. Take a point B, on line remote from C, and with same radius, describe an arc. Draw a line through C, tangent to this arc and it will be parallel to the given line AB.

Second method.—In fig. 9,316, from A, the given point, describe the arc FD, cutting the given line at F; from F, with the same radius, describe the arc EA, and set off FD, equal to EA. Draw the parallel through the points AD.

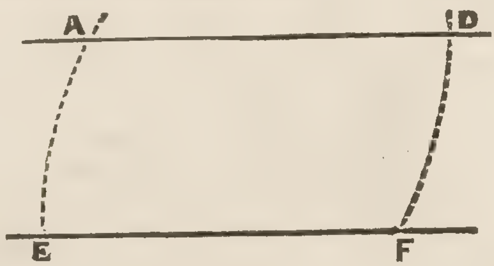


FIG. 9,316.—***Problem 5.*** Second method.

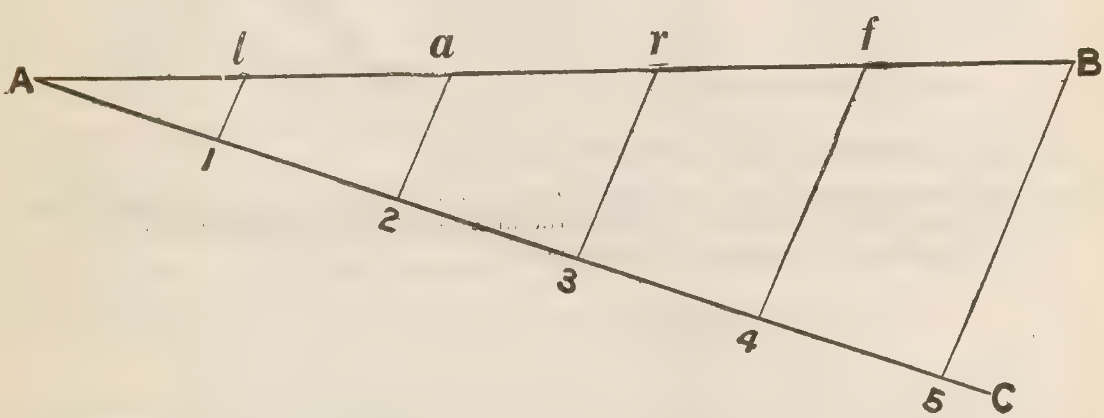


FIG. 9,317.—***Problem 6.*** *To divide a line into a number of equal parts.*

Problem 6.*—To divide a line into a number of equal parts.*

In fig. 9,317, assuming line AB, is to be divided into say 5 parts, draw a diagonal line AC, and space off 5 unit lengths. Join B5, and through the points 1,2,3,4, draw lines 1*l*, 2*a*, etc., parallel to B5, then will AB, be divided into five equal parts, A*l*, *la*, *ar*, *rf*, and *f*B.

Problem 7.*—Upon a straight line to draw an angle equal to a given angle.*

In figs. 9,319 and 9,320, let A, be the given angle and FG, the line

With any radius from the points A and F, describe arcs DE, and IH, cutting the sides of the angle A, and the line FG.

Set off the arc IH, equal to DE, and draw FH. The angle F, is equal to angle A, as required.

***Problem 8.**—To bisect an angle.*

In fig. 9,321 let ACB, be the angle; with center C, describe an arc

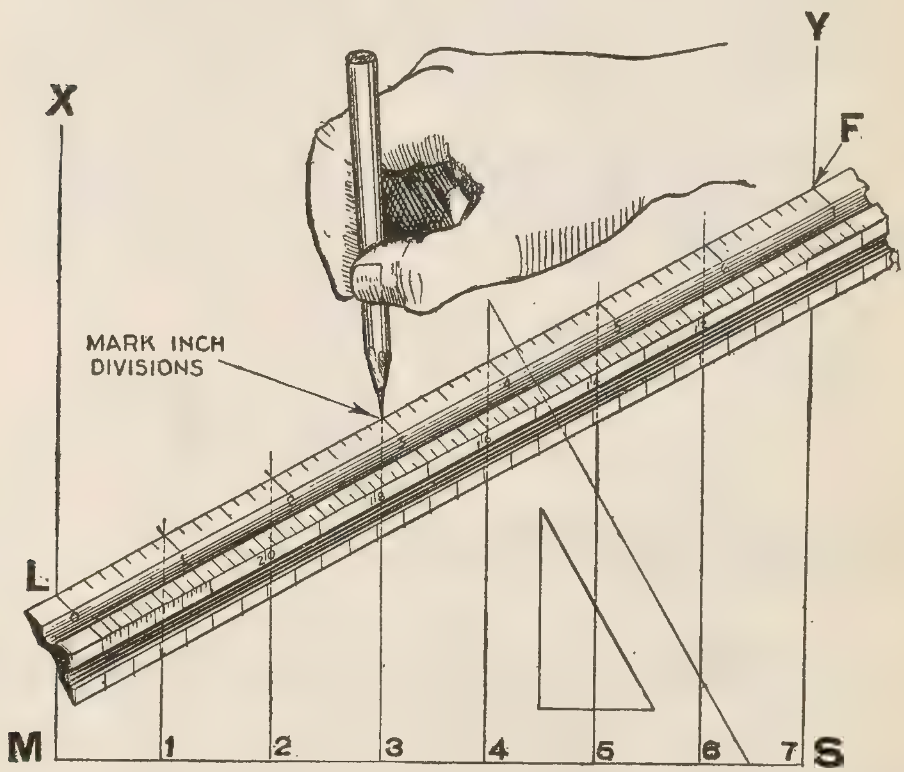
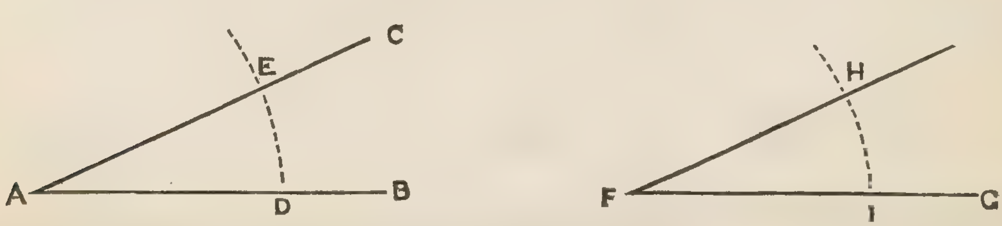


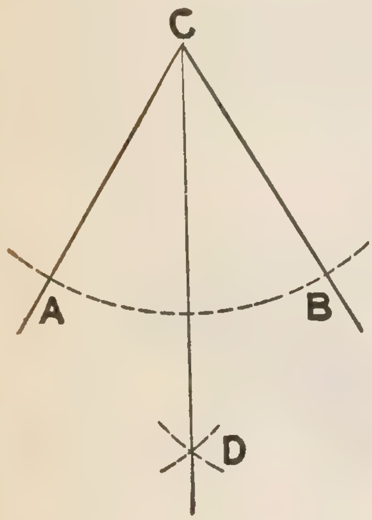
FIG. 9,318.—To divide a given line into any number of equal parts without dividers. Let M S, be the line and say it is to be divided into seven equal parts. Erect perpendiculars M X and S Y. Lay the O, mark of the scale on the line M X, and place scale at such angle that coincides with line S Y. Draw a light line L F, and mark the inch division as shown. With a triangle and T square draw lines from the points on L F, to M S, cutting M S, at 1, 2, 3, etc., which divide M S, into seven equal parts.



FIGS. 9,319 and 9,320.—***Problem 7.*** *Upon a straight line to draw an angle equal to a given angle.*

cutting the sides at A and B. On A and B, as centers describe arcs cutting at D. A line through C and D will divide the angle into two equal parts.

Problem 9.—To find the center of a circle.



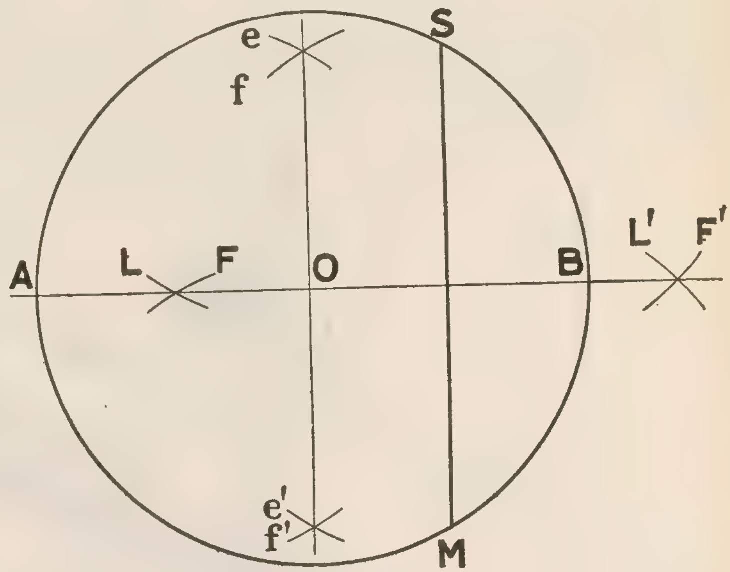
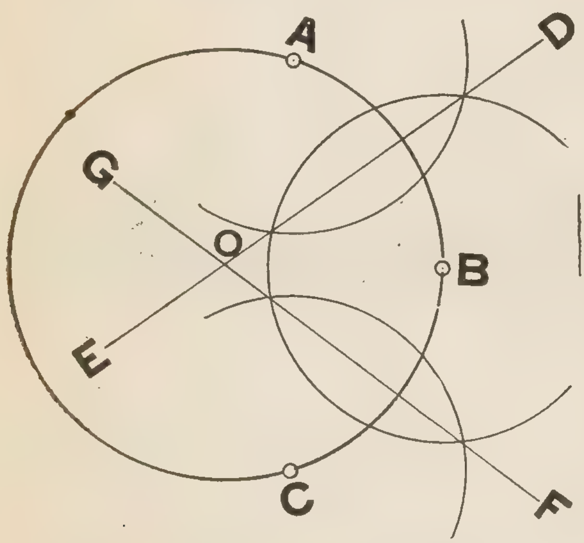


Fig. 9,321.—***Problem 8.*** *To bisect an angle.*
Fig. 9,322.—***Problem 9.*** *To find the center of a circle.*



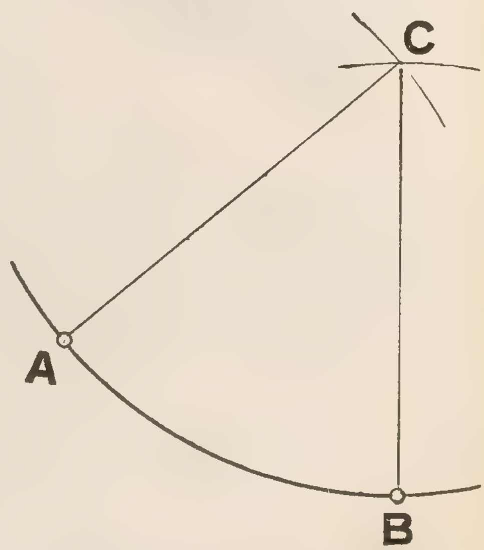


Fig. 9,323.—***Problem 9.*** *Second method.*
Fig. 9,324.—***Problem 10.*** *Through two given points to describe an arc of a circle with a given radius.*

In fig. 9,322 draw any chord as MS. With M and S, as centers and any radius, describe arcs L,F, and L′,F′, and a line through their intersection, giving a diameter AB. Applying same construction with centers A and B, describe arcs *ef*, and *e′ f′*. A line drawn through the intersections of these arcs will cut AB, at O, the center of the circle.

Problem 9.—*Second method.* To find the center of a circle.

In fig. 9,323, select three points, A,B,C, in the circumference, well apart; with the same radius; describe arcs from these three points cutting each other, and draw two lines DE, FG through their intersections. The point O, where they cut is the center of the circle or arc.

Problem 10.—*To describe a circle passing through three given points.*

In fig. 9,323, let A,B,C, be the given points and proceed as in last problem to find the center O, from which the circle may be described. This problem

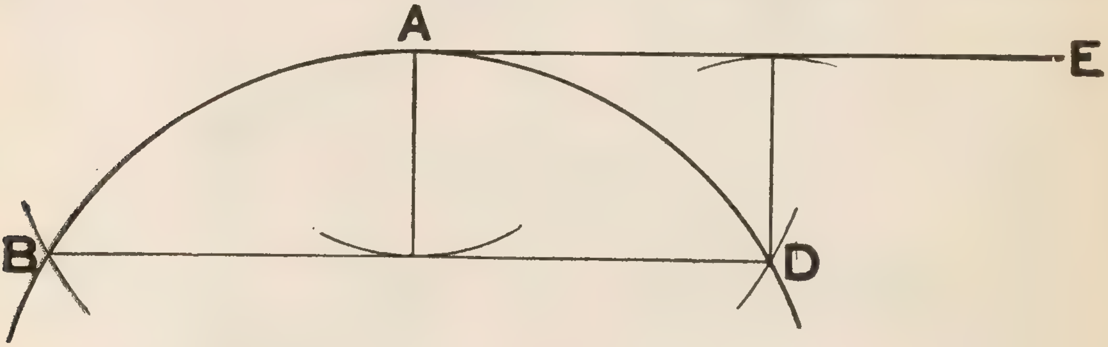


Fig. 9,325.—*Problems 11 and 12. To describe a circle passing through three given points, and to draw a tangent to a circle from a given point in the circumference.*

is useful in such work as laying out object of large diameter as an arch, when the span and rise are given.

Problem 11.—*Through two given points to describe an arc of a circle with a given radius.*

In fig. 9,324, take the given points A and B, as centers, and, with the given radius, describe arcs cutting at C; from C, with the same radius, describe the required arc AB.

Problem 12.—*To draw a tangent to a circle from a given point in the circumference.*

In fig. 9,325, from A, set off equal segments AB, AD; join BD, and draw AE, parallel to it, for the tangent.

***Problem 13.**—On a given straight line A5, to construct any regular polygon say a pentagon.*

In fig. 9,326 produce the given side A5, say to the left. With center A, and radius A5, describe a semi-circle. Divide the semi-circle into as many equal parts as the polygon is to have sides; in this case 5 equal parts, by trial with

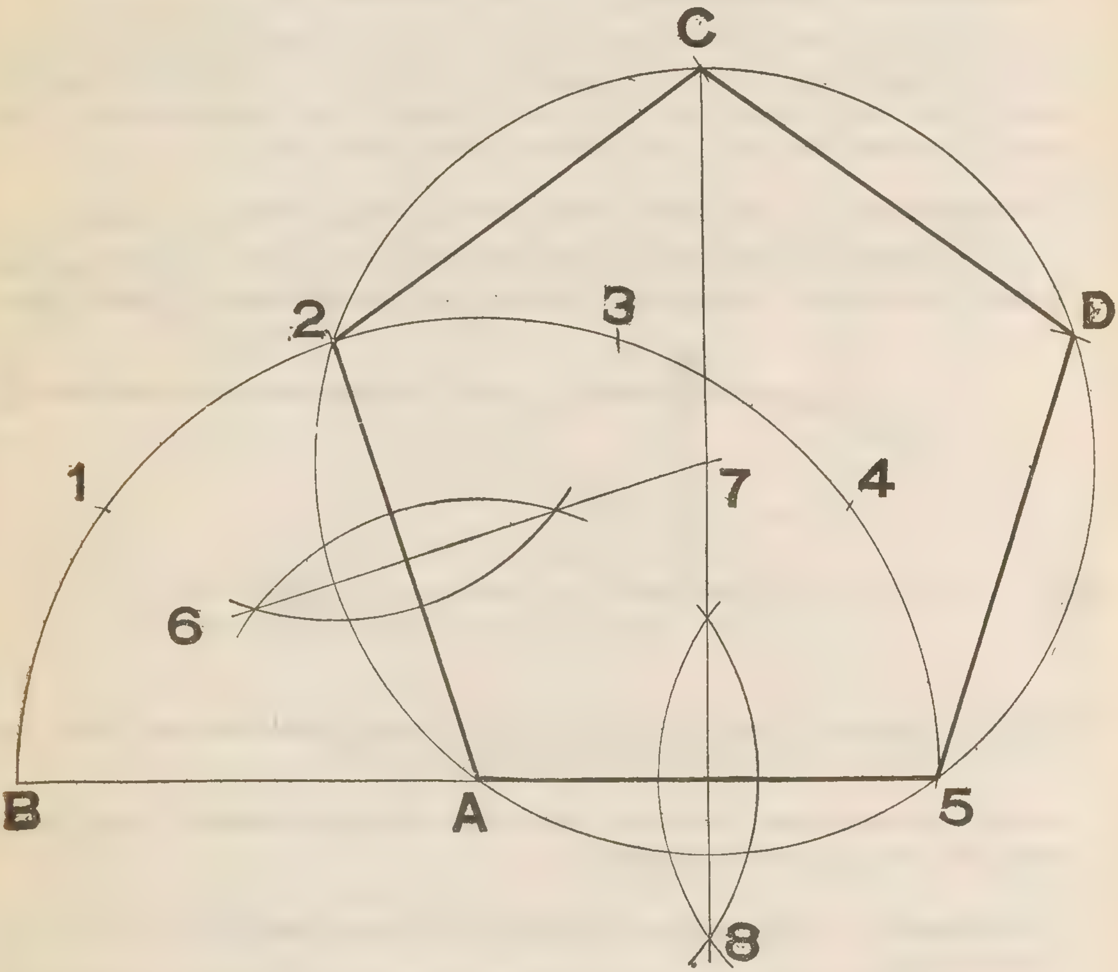


FIG. 9,326.—***Problem 13.*** *On a given straight line, to construct a regular polygon*

compasses. From A, draw A2, which gives another side of the polygon; and no matter how many sides the polygon is to have, always draw from A, to the second division on the semi-circle. Bisect the sides 2 A, A 5, by lines 6 7, and 8 7, intersecting at point 7, which is the center of the polygon. With center 7, and radius 7 A, describe the circle. Mark off, on the circumference, the divisions 2C, CD, equal to A5. Joint 2C, CD, D5. Then A2CD5, is the required regular polygon.

Problem 14.*—To ascertain approximately, the length of the circumference of a given circle.*

In fig. 9,327 draw a diameter AB. Find center C. Draw AD, perpendicular to AB, and 3 times the length of the radius. Draw BE, perpendicular to AB. With 30° triangle, draw angle BCH = 30°. Mark joint J, on BE. Join J D. Then line J D, is (approximately) equal to half the circumference; and twice J D = the whole circumference. This method is sufficiently accurate for all practical work, because the result is wrong only by about the $\frac{1}{100,000}$

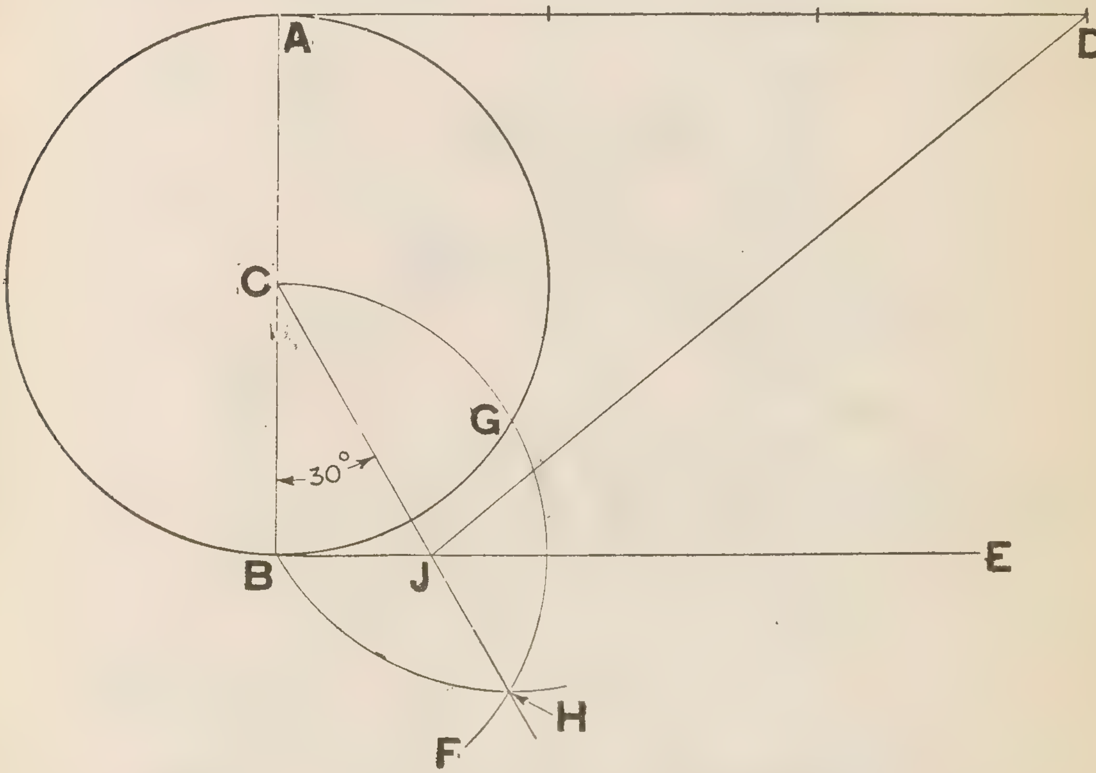


FIG. 9,327—***Problem 14.****—To ascertain approximately, the length of the circumference of a given circle.*

part. This problem helps to ascertain approximately, the length of certain portions of the circumference. Thus ⅓ of JD = ⅙ of the circumference. Archimedes demonstrated that the diameter is to the circumference, within a minute fraction, as 7 is to 22, or 1 to $3^1/_7$. Thus, for all practical purposes, it may be assumed that if the diameter = 1 in., the circumference = $3^1/_7$ ins. To describe a circle having a circumference equal to the circumferences of any number of given equal or unequal circles: *Draw a line equal to the sum of the diameters of the given circles. This line is the diameter of the required circle.*

***Problem 15.**—To find the center of a given circle, or arc of a circle.*

In fig. 9,328, draw any two chords, 12 and 23. Bisect these chords by perpendiculars 45, and 67, intersecting at A. Point A, is the center of the circle or arc. The chords are not obliged to meet at 2. They may be drawn anywhere in the circle or arc, but it is better, when possible, to let them be at about right angles to each other. The chords may intersect. They should not be made too short.

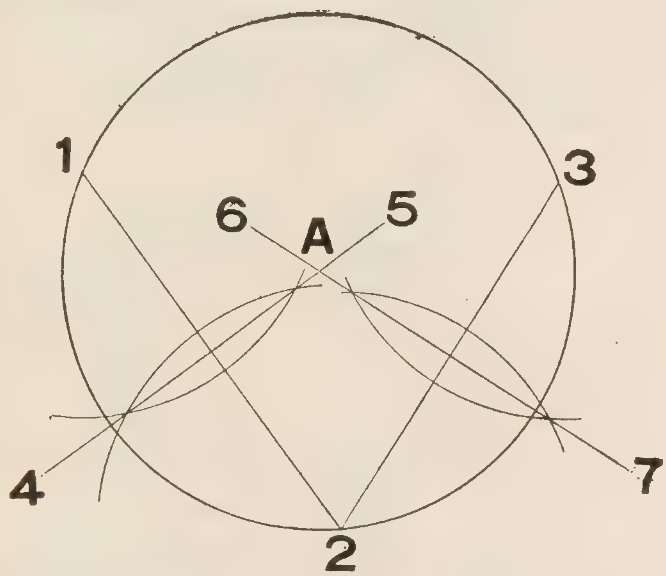


FIG. 9,328—***Problem 15**—To find the center of a given circle, or arc of a circle.*

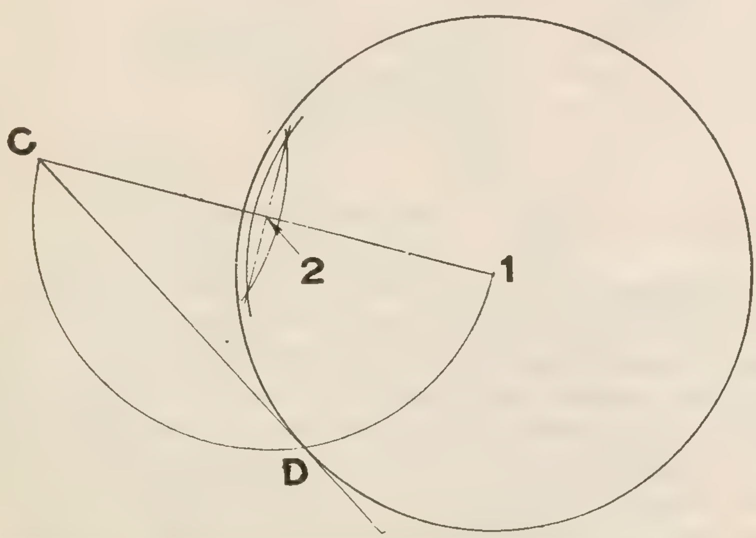


FIG. 9,329—***Problem 16**—To draw a tangent to a given circle from any given point.*

***Problem 16.**—To draw a tangent to a given circle from any given point C, outside the circle.*

In fig. 9,329, 1, is the center of the given circle. Join C1. Bisect C1, at 2; and with center 2, and radius 2 C, or 21, describe a semi-circle, cutting the circle at D. Point D, is the point of contact. Through D, draw CD, which is the required tangent.

CD, is tangent because a line through the point of contact D, and center 1, of the circle makes a right angle with CD. Why?

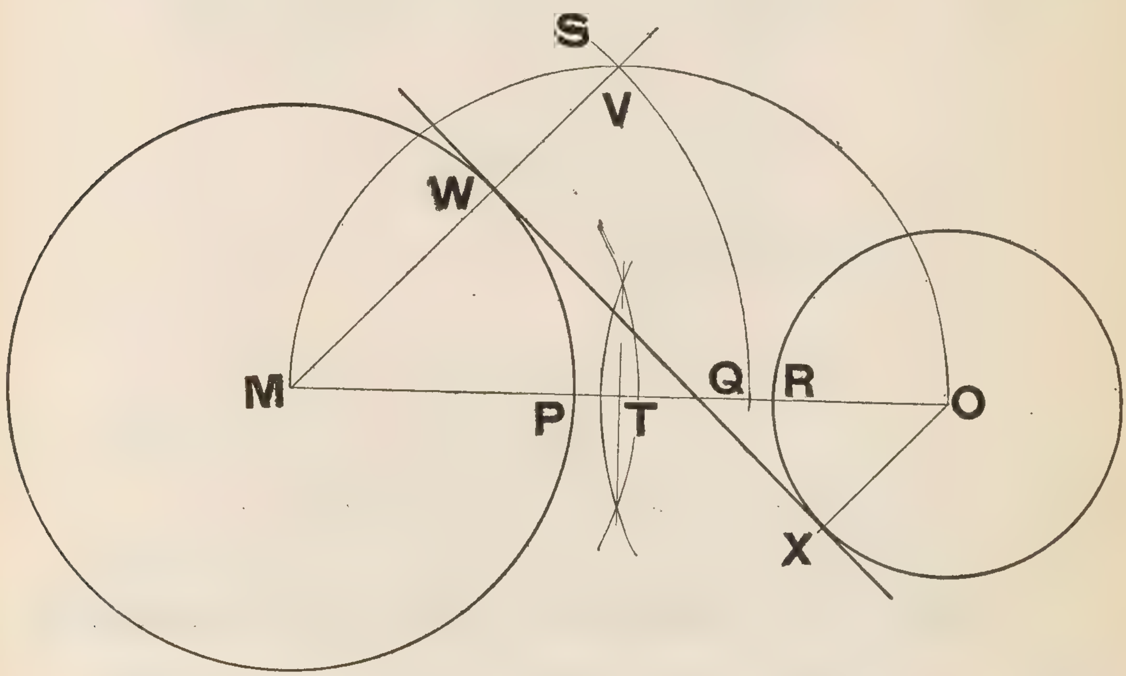


FIG. 9,330.—***Problem 17**—To draw an interior tangent to two unequal circles.*

***Problem 17.**—To draw an interior tangent to two unequal circles M and O.*

In fig. 9,930, join centers M and O. Bisect MO, at T, and describe a semi-circle on MO. From P, on the larger circle, mark off PQ = OR, the radius of the smaller circle. With center M, and radius MQ, describe arc QS, cutting the semi-circle at V. Join MV, and mark point W. Draw OX. parallel to MV. Through the points of contact W and X, draw the interior tangent WX.

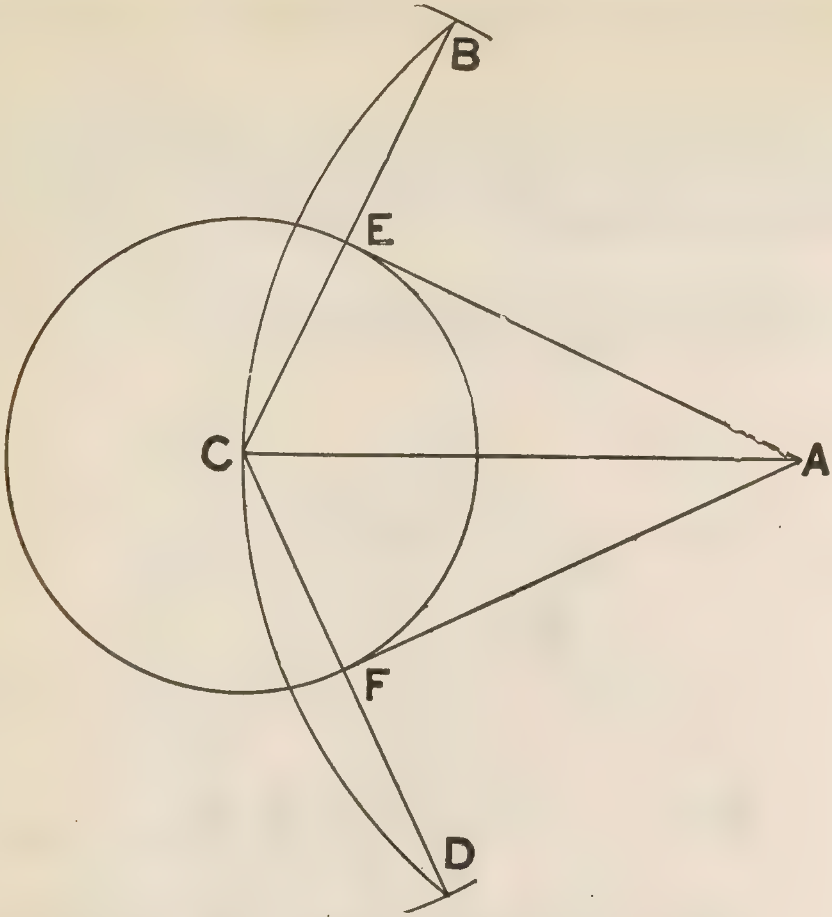


FIG. 9,331.—*Problem 18—To draw tangents to a circle from points without.*

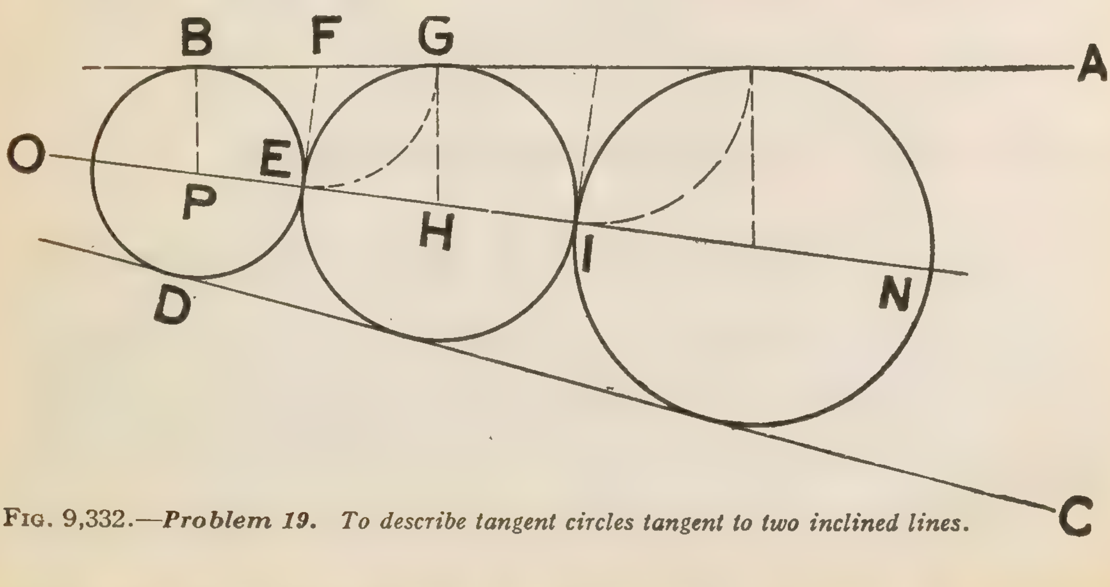


FIG. 9,332.—*Problem 19. To describe tangent circles tangent to two inclined lines.*

Problem 18.—*To draw tangents to a circle from points without.*

In fig. 9,331, from A, and with the radius AC, describe an arc BCD, and from C, with a radius equal to the diameter of the circle, cut the arc at BD; join BC, CD, cutting the circle at EF, and draw the tangents, AF, AE.

Problem 19.—*Between two inclined lines to describe a series of circles tangent to these lines and tangent to each other.*

In fig. 9,332, bisect the inclination of the given lines AB, CD, by the line NO. From a point P, in this line, draw the perpendicular PB, to the line AB, and about P, describe the circle BD, touching the lines and cutting the center line at E. From E, draw EF, perpendicular to the center line, cutting

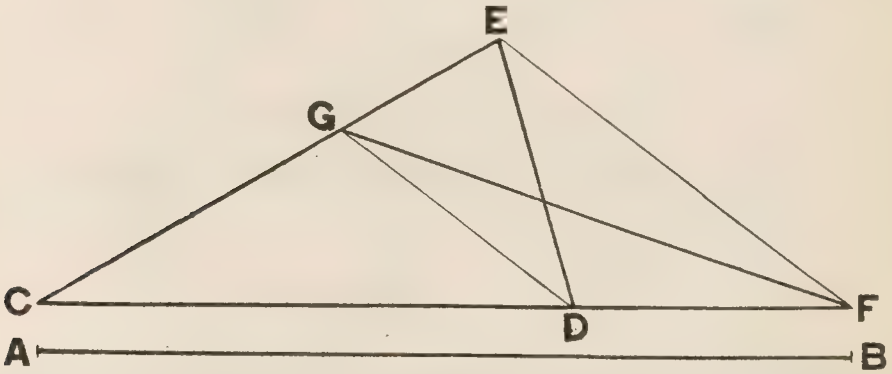


FIG. 9,333 and 9,334—*Problem 20.*—*To construct a triangle having a given base and equivalent to any rectilineal figure.*

AB, at F, and about F, describe an arc EG, cutting AB, at G. Draw GH, parallel to BP, giving H, the center of the next circle, to be described with the radius HE, and so on for the next circle IN.

Problem 20.—*To construct a triangle, having a given base A B, and equivalent to any rectilineal figure, say equal in area to the triangle CDE.*

In figs. 9,333 and 9,334 produce one side CD, to F, making CF, equal to the given base AB. Join FE. Draw DG, parallel to FE. Join FG. Then CFG, is the required triangle.

Problem 21.—*To construct a rectangle, when each of the diagonals is equal to A B, and each of one pair of opposite sides is equal to C D.*

In figs. 9,335 and 9,336 bisect AB at 1, and with center 1, and radius 1A, describe a circle. With centers A and B, and radius CD, obtain points 2 and 3. Join A2, 2B, B3, 3A. Then A2B3 is the required rectangle. If

the longer side A2 be given, instead of the shorter side, then describe arcs at 2 and 3, with the longer side as radius.

Problem 22.—*To construct a square, whose diagonal is given.*

Bisect R S, by a perpendicular 2 3. Cut off 1 4, and 1 5, equal to 1R, or 1S. Join R5, 5S, S4, 4R. Then R5S4 is the square required, having a given diagonal RS.

Problem 23.—*To construct a square equal in area to any number of given squares.*

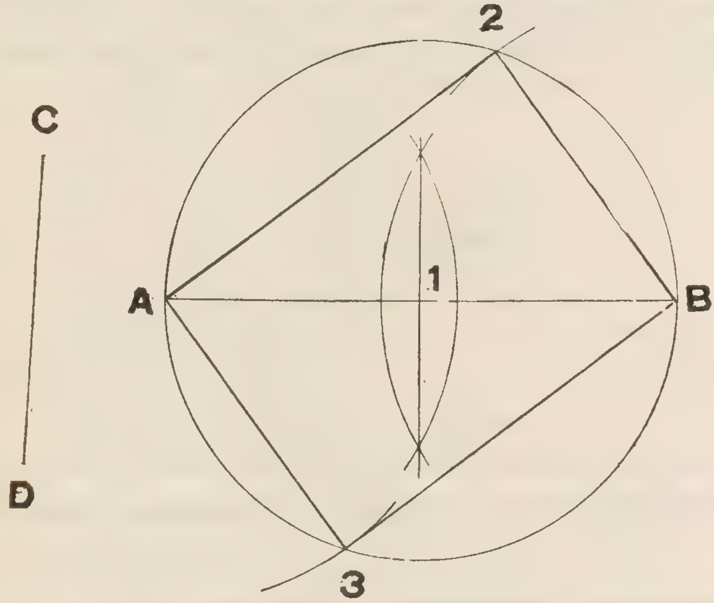


FIG. 9,335 and 9,336.—***Problem 21.***—*To construct a rectangle when each of diagonals is equal to a given line and each of one pair of opposite sides is equal to another given line.*

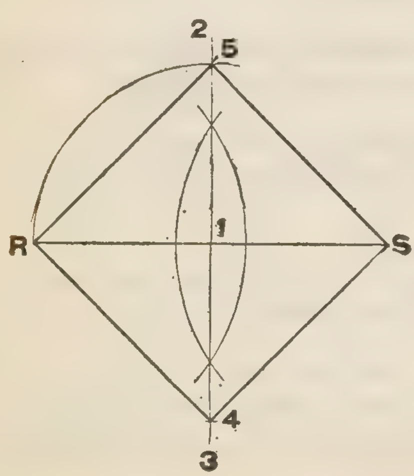
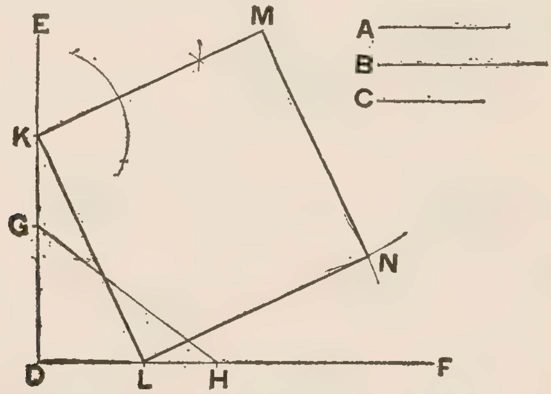


FIG. 9,337.—***Problem 22.***—*To construct a square with given diagonal.*

Let A, B, C be the side of the three given squares. Make D G = A and D H = B. Join G H. Then the square upon G H equals the squares upon A and B. Make D K = G H and D L = C. Join K L. Then the square K L N M, equals the three squares upon A, B and C.



FIGS. 9,338 to 9,341.—*Problem 23,—To construct a square equal in area in any number of given squares.*

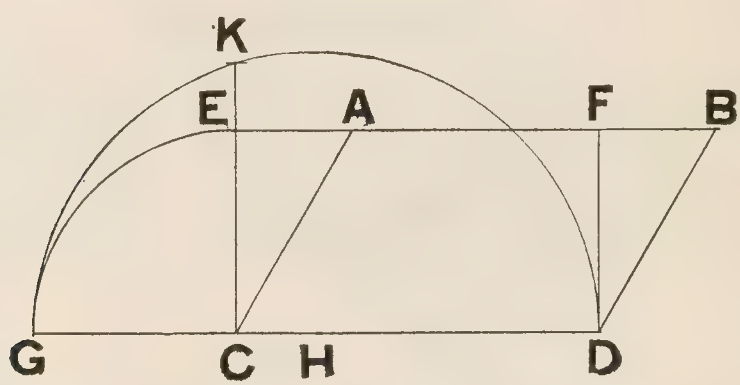


FIG. 9,342.—*Problem 24.—To construct a square, equal in area to any parallelogram.*

Problem 24.*—To construct a square, equal in area to any parallelogram. Thus, construct a square equivalent to the rhomboid C D B A.*

In fig. 9,342, make the rectangle C D F E, equal to C D B A, by producing E F, and erecting perpendiculars C E, D F. Produce D C. Make C G, = C E. Bisect G D, at H. With center H, and radius H G, describe a semicircle. Produce C E, to K. Then C K, is the mean proportional to G C, C D, and a square constructed with C K as a side is equal in area to the rhomboid C D B A.

Problem 25.*—On a given line to construct a parallelogram equivalent to any rectilineal figure, say to the given rectangle E F D C.*

Produce E F, to G, making F G, equal to the given line. Produce E C, indefinitely

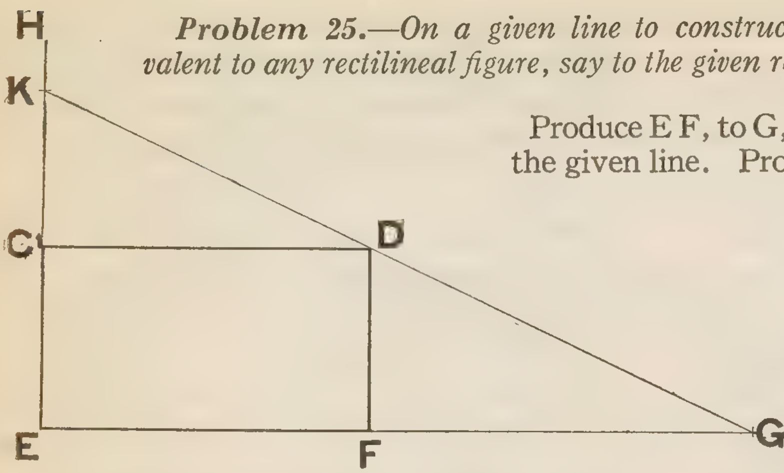


FIG. 9,343.—***Problem 25.****—On a given line to construct a parallelogram equivalent to any rectilineal figure.*

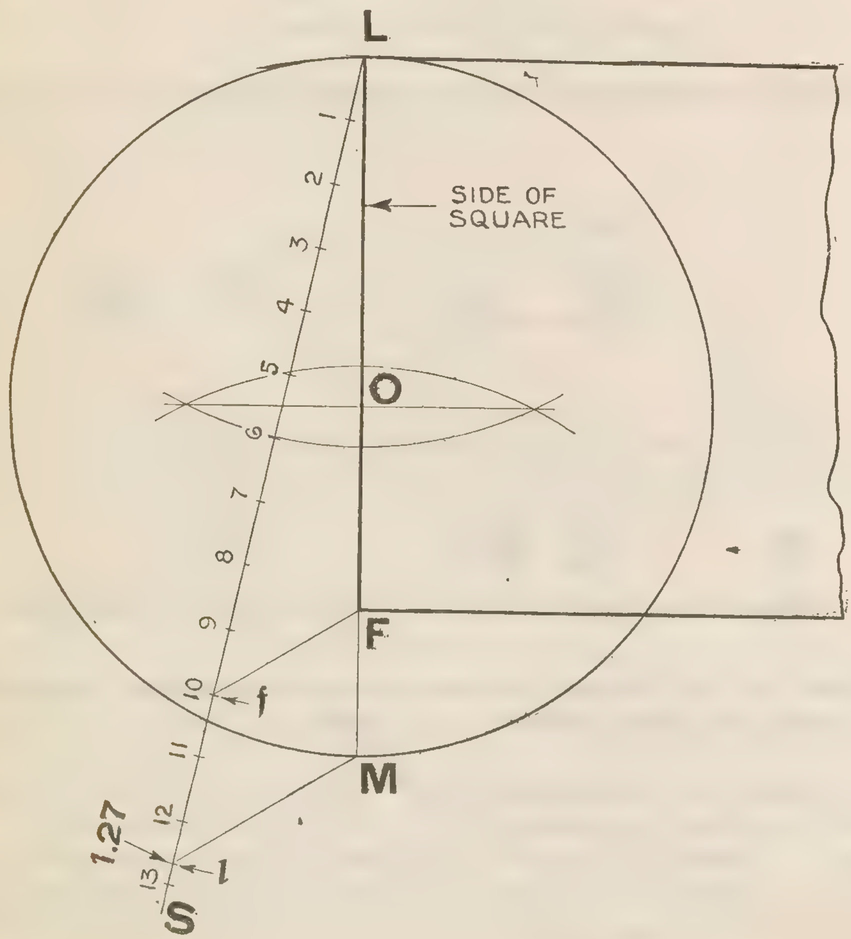


FIG. 9,344.—***Problem 26.****—To construct a circle equal in area to a given square.*

to H. Through D, draw G K. Then C K, is the perpendicular height of the required parallelogram. If the given figure be a square, proceed as above. An equivalent rhomboid can be constructed upon the given line, having an altitude equal to C K, or an equivalent triangle, by making its altitude twice as long as C K.

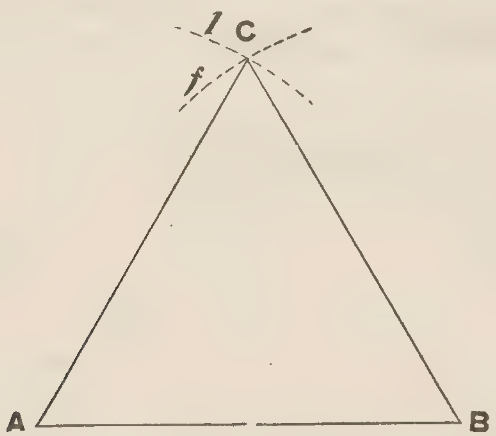


FIG. 9,345.—***Problem 27.*** *To construct an equilateral triangle on a given base.*

Problem 26.—To construct a circle equal in area to a given square.

In fig. 9,344, let L F, be side of the given square. Through L, draw proportional line L S, and with any convenient scale divide it into 13 equal parts. At the point *f*, or 10th division, draw line *f* F, and at a point *l*, between 12 and 13, and $^7/_{10}$ of a division from 12, draw *l* M, parallel to *f* F. L M, is diameter of the required circle. Why? Bisect this diameter at O and with radius O L describe the required circle.

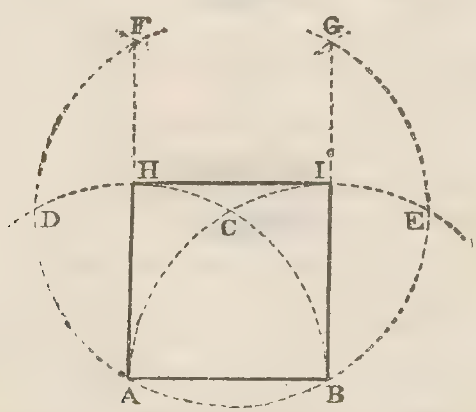


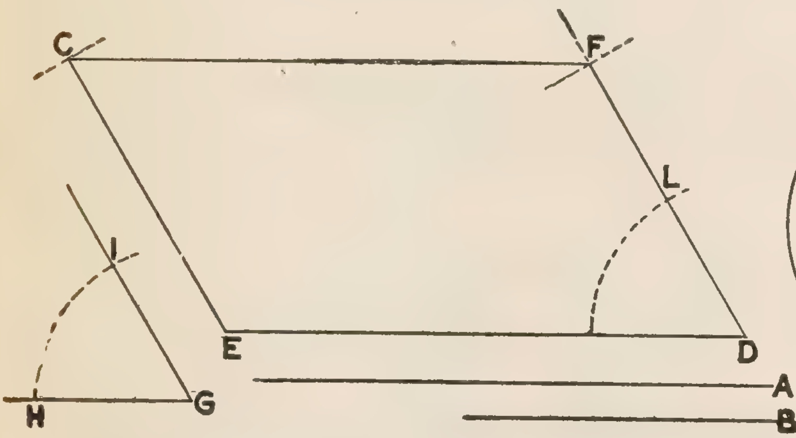
FIG. 9,346.—***Problems 28 and 29.*** *To construct a square on a given base.*

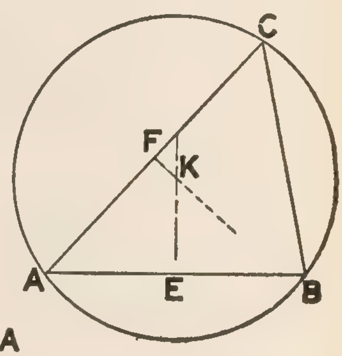
***Problem 27.**—To construct an equilateral triangle on a given base.*

In fig. 9,345, with A, and B, as centers and radius equal to AB, describe arcs *l* and *f*. At their intersection C, draw lines CA, and CB, sides of the required triangle.

***Problem 28.**—To construct a square on a given base.*

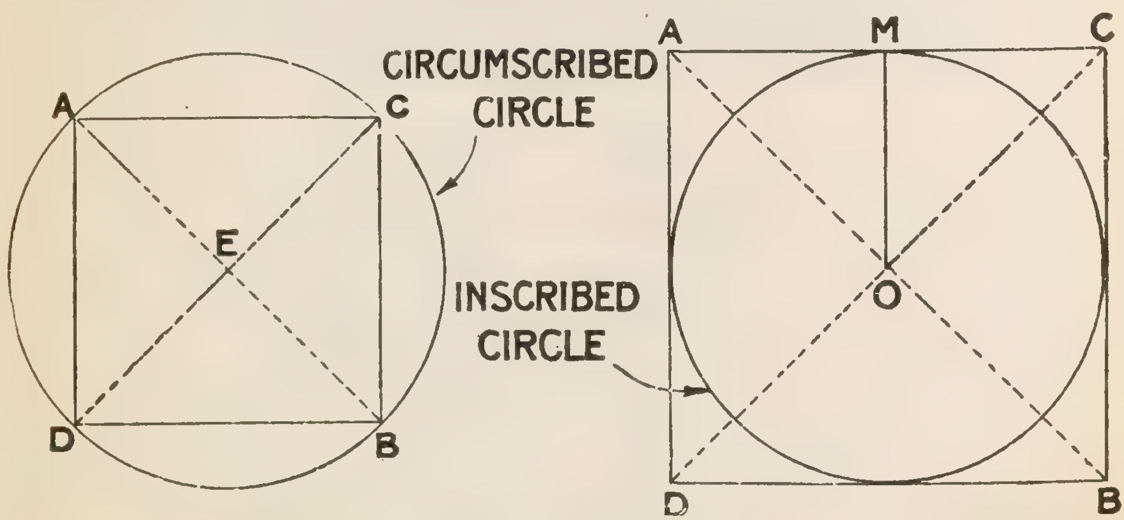
In figs. 9,346, with end points A and B, of base as centers and radius equal to AB, describe arcs cutting at C; with C as center, describe arcs





FIGS. 9,347 to 9,349.—***Problem 30.*** *To construct a parallelogram having given the sides and an angle.*

FIG. 9,350.—***Problem 31.*** *To describe a circle about a triangle.*



FIGS. 9,351 and 9,352.—***Problem 32.*** *To circumscribe* (fig. 9,351) *and inscribe* (fig. 9,352) *a circle about a square.*

cutting the others at DE; and with D and E, cut these at FG. Draw AF, and BG, and join the intersections HI, then ABIH is the required space.

***Problem 29.**—To construct a rectangle on a given base.*

In fig. 9,346, let AB, be given base. Erect perpendiculars at A and B, equal to altitude of the rectangle, and join their ends H and I, by line HI, ABIH, is the rectangle required.

***Problem 30.**—To construct a rectangle having given the sides and an angle.*

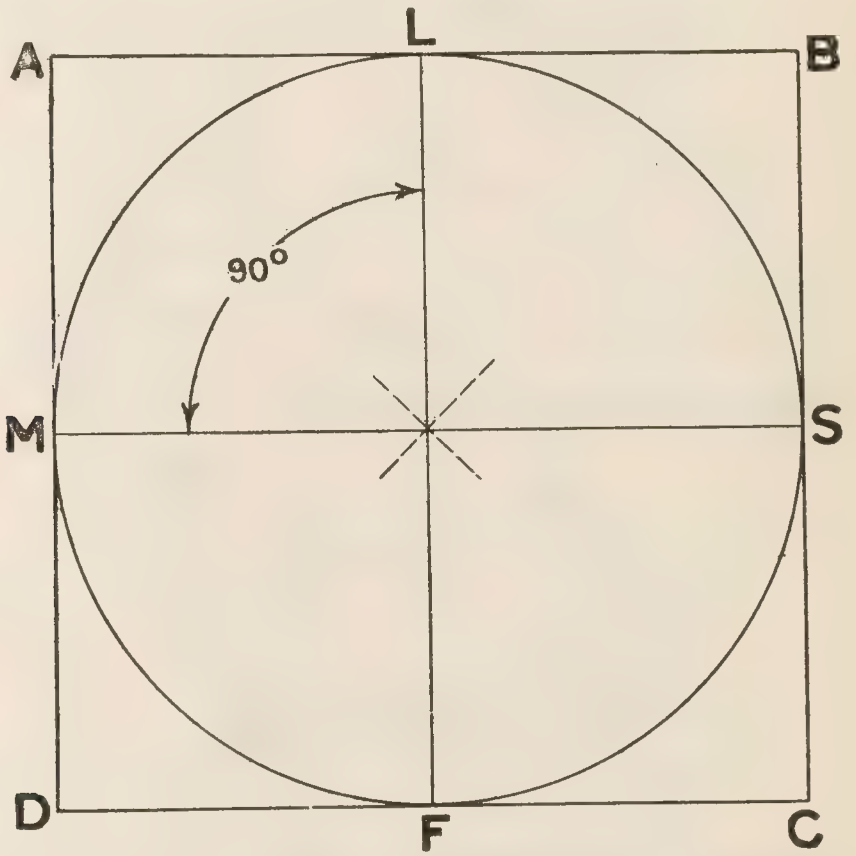


FIG. 9,353.—***Problem 33.**—To circumscribe a square about a circle. Second method.*

In figs. 9,347 to 9,349, draw side DE, equal to the given length A, and set off the other side DF, equal to the other length B, forming the given angle IGH. From E, with DF, as radius, describe an arc, and from F, with the radius DE, cut the arc at C. Draw FC, EC. Or, the remaining sides may be drawn as parallels to DE, DF.

***Problem 31.**—To describe a circle about a triangle.*

In fig. 9,350, bisect two sides AB, AC, of the triangle at E and F, and

from these points draw perpendiculars intersecting at K. From the center K, with the radius KA, describe the circle ABC.

***Problem 32.**—To circumscribe and inscribe a circle about a square.*

In fig. 9,351, draw the diagonals AB and CD, intersecting at E. With

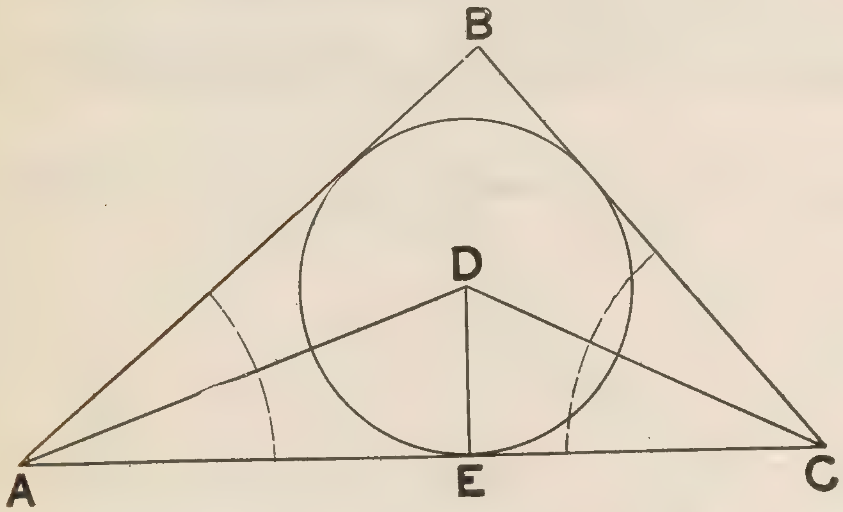


FIG. 9,354.—***Problem 34.** To inscribe a circle in a triangle.*

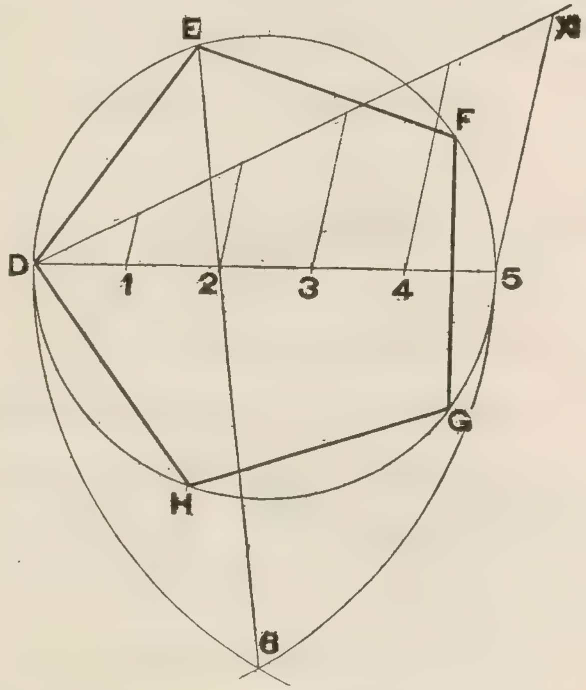


FIG. 9,355.—***Problem 35.**—To inscribe any regular polygon in a given circle.*

radius EA, circumscribe the circle. To inscribe a circle let fall from the center (as just found) a perpendicular to one side of the sqaure as OM, in fig. 9,352. With radius OM, inscribe the circle.

Problem 33.—To circumscribe a square about a circle.

In fig. 9,353, draw diameters MS and LF, at right angles to each other. At the points M, L, S, F, where these diameters cut the circle, draw tangents that is, lines perpendicular to the diameter, thus obtaining the sides of the circumscribed square ABCD.

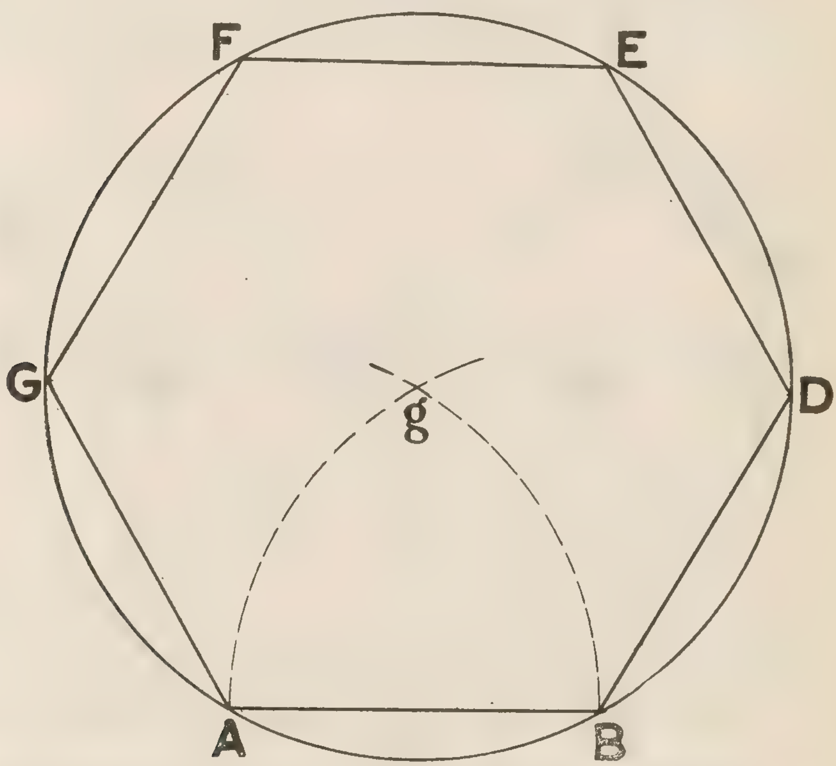


FIG. 9,356.—***Problem 37.*** *To construct a hexagon upon a given straight line.*

Problem 34.—To inscribe a circle in a triangle.

In fig. 9,354, bisect two of the angles A and C, of the triangle by lines cutting at D; from D, draw a perpendicular DE, to any side, and with DE, as radius, describe a circle.

Problem 35.—To inscribe any regular polygon in a given circle.

In fig. 9,355, draw a diameter D 5. Divide D 5, into as many equal parts, as the polygon is to have sides, in this case, five equal parts. With points D and 5, as centers, and the diameter D 5, as radius, describe arcs intersecting at 6. From 6, draw a line through Point 2 to E. Join D E, which

is one side of the required polygon. Make E F, F G, G H, each equal D E. Join E F, F G, G H, H D. Then D E F G H, is the required polygon.

This method is only approximately correct. It is however, sufficiently accurate for all practical work. On the same principle, an arc can (approximately) be divided into any number of equal parts, or a circle into equal sectors. By this method, a regular polygon having any number of sides

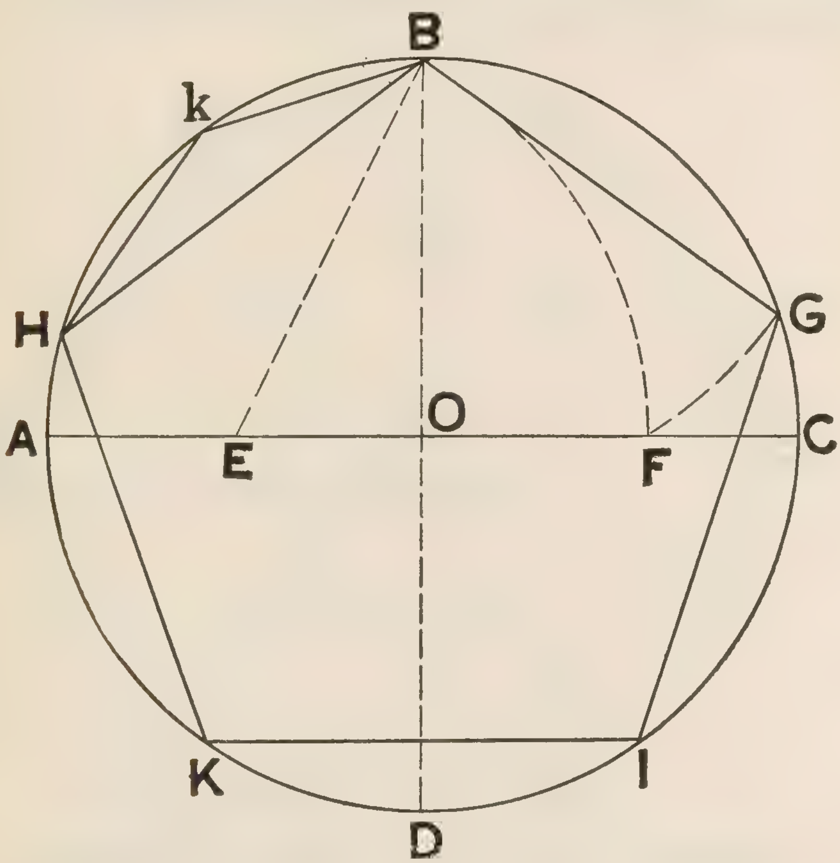


Fig. 9,357.—***Problem 36.*** *To inscribe a pentagon in a circle.*

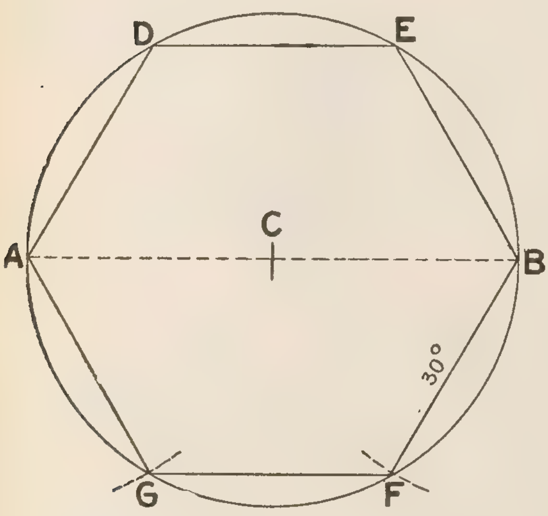
can be inscribed, (approximately) within a given circle. If a nonagon is to be inscribed, divide the diameter into nine equal parts, and then proceed as above. To get the first side of the polygon, always draw a line from point 6; through the 2nd division on the diameter, no matter how many sides the polygon is to have. In a polygon, that has an even number of sides, a line drawn from one angle to the opposite angle (a diagonal) passes through the center. When there is an odd number of sides, a line from an angle through the center, bisects the opposite side. Note these facts as tests for accuracy in the work.

Problem 36.—To inscribe a pentagon in a circle.

In fig. 9,357, draw two diameters, AC, BD, at right angles intersecting at O; bisect AO, at E, and from E, with radius EB, cut AC, at F, and from B, with radius BF, cut the circumference at G,H, and with the same radius step round the circle to I and K; join the points so found to form the pentagon.

Problem 37.—To construct a hexagon upon a given straight line.

In fig. 9,356, from A and B, the ends of the given line describe arcs intersecting at g, from g; with the radius gA, describe a circle. With the same radius set off the arcs AG, GF and BD, DE. Join the points so found to form the hexagon.



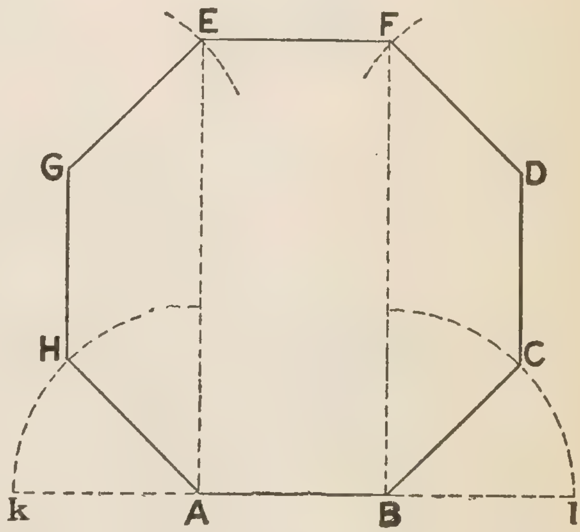


FIG. 9,358.—***Problem 38.*** *To inscribe a hexagon in a circle.*
FIG. 9,359.—***Problem 39.*** *To describe an octagon on a given straight line.*

Problem 38.—To inscribe a hexagon in a circle.

In fig. 9,358, draw a diameter ACB; from A and B, as centers with the radius of the circle AC, cut the circumference at D, E, F, G, and draw AD, DE, etc., to form the hexagon.

The points DE, etc., may be found by stepping the radius (with the dividers) six times round the circle.

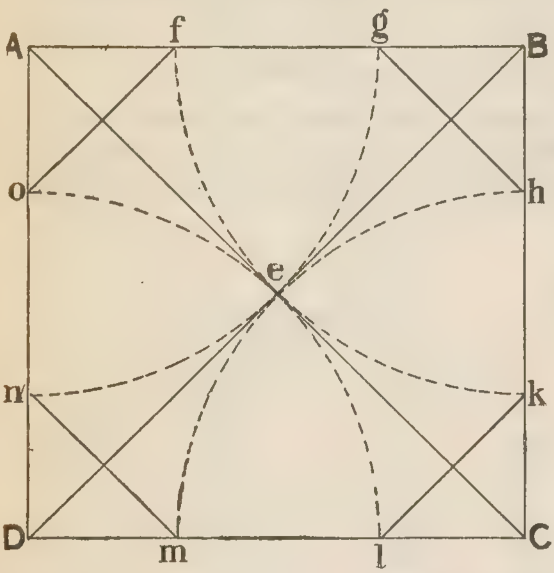
Problem 39.—To describe an octagon on a given straight line.

In fig. 9,359, produce the given line AB, both ways, and draw perpendiculars AE, BF; bisect the external angles A and B, by the lines AH, BC, which make equal to AB. Draw CD and HG, parallel to AE and equal to

AB; from the center GD, with the radius AB, cut the perpendiculars at EF, and draw EF, to complete the hexagon.

Problem 40.—*To inscribe an octagon in a square.*

In fig. 9,360, draw the diagonals of the square intersecting at *e;* from the



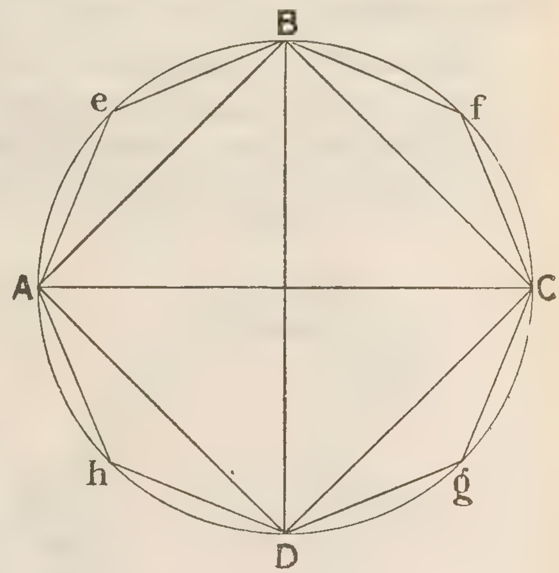
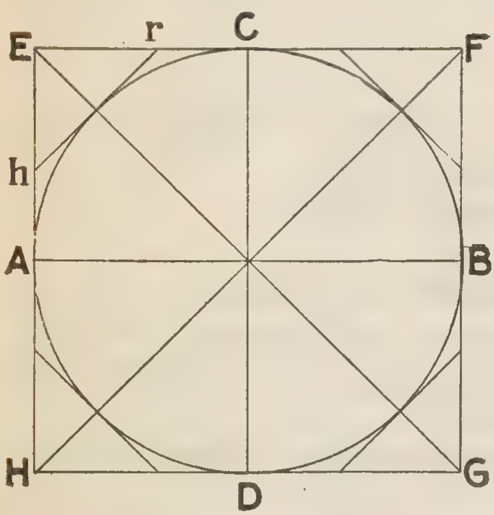


FIG. 9,360.—***Problem 40.*** *To inscribe an octagon in a square.*
FIG. 9,361.—***Problem 41.*** *To inscribe an octagon in a circle.*



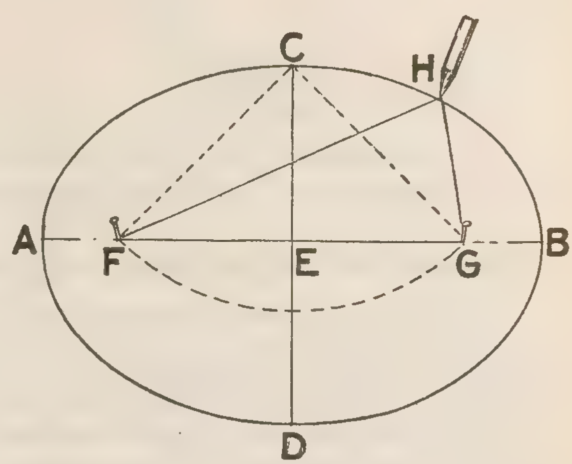


FIG. 9,362.—***Problem 42.*** *To circumscribe an octagon about a circle.*
FIG. 9,363.—***Problem 43.*** *To describe an ellipse when the two axes are given.*

corners A,B,C,D, with A*e*, as radius, describe arcs cutting the sides at *g*, *h*, etc.; and join the points so found to complete the octagon.

Problem 41.—To inscribe an octagon in a circle.

In fig. 9,361, draw two diameters AC, BD, at right angles; bisect the arcs AB, BC, etc., at *e*, *f*, etc., and join the points of division to form the octagon.

Problem 42.—To circumscribe an octagon about a circle.

In fig. 9,362, circumscribe a square EFGH, about the given circle. Draw

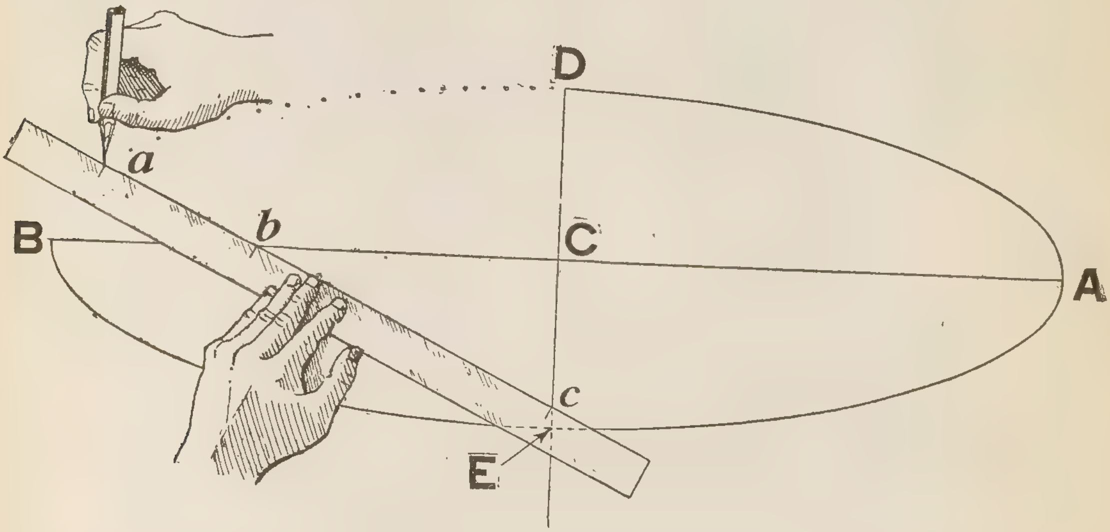


FIG. 9,364.—*Problem 43.* Second method.

diagonals HF and EG, and tangents *h r*, etc., through points where the diagonals cut the circle to form with the intercepts, the octagon.

Problem 43.—To describe an ellipse when the two axes are given.

In fig. 9,363, draw the major and minor axes AB and CD, at right angles, intersecting at E. On the center C, with AE, as radius, cut the axis AB, at F and G, the *foci;* insert pins through the axis at F and G, and loop a thread or cord upon them equal in length to the axis AB, so that when stretched it reaches the extremity C, of the *minor axis*, as shown in dotted lines. Place a pencil inside the cord, as at H, and guiding the pencil in this way, keeping the cord equally in tension, carry the pencil round the pins FG, and so describe the ellipse.

Second Method.—In fig. 9,364 along the edge of a piece of paper, mark off a distance *ac*, equal to AC, half the major axis, and from the same point, a distance *ab*, equal to CD, half the minor axis. Place the slip so as to bring the point *b*, on the line AB, or major axis, and the point *c*, on the line DE, or minor axis. Set off the position of the point *a*. Shifting the slip, so that the point *b*, travels on the major axis, and the point *c*, on the minor axis, any number of points in the curve may be found, through which the curve may be traced.

***Problem 44.**—To construct a spiral or volute, by means of tangential arcs of circles.*

Construct a square 1 2 3 4, and produce the sides as shown. With center 2, and radius 2 1, describe arc 1 A; center 3, and radius 3 A, describe arc A B; center 4, and radius 4 B, describe arc B C; center 1, and radius 1 C, describe C D; center 2, and radius 2 D, describe D E. In the same way describe any number of arcs, E F, F G, G H. The curve obtained is a spiral or volute. 1 2 3 4, is the eye of the spiral. The eye can be formed by any regular or irregular rectilineal figure, not having a re-entrant angle. In every case, proceed as above.

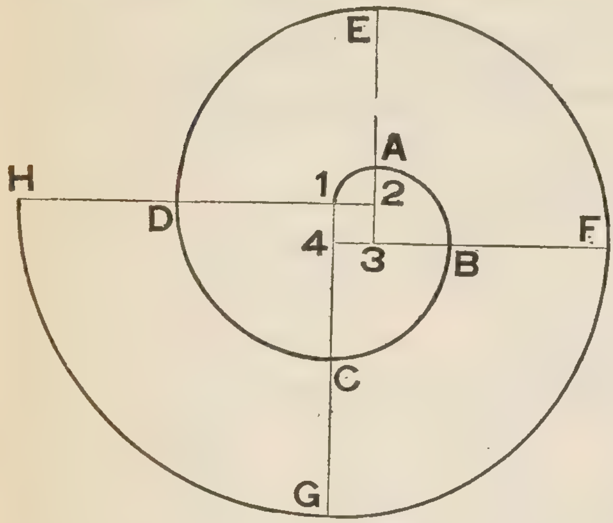


Fig. 9,365.—***Problem 44.***—To construct a spiral or volute, by means of tangential arcs of circles.

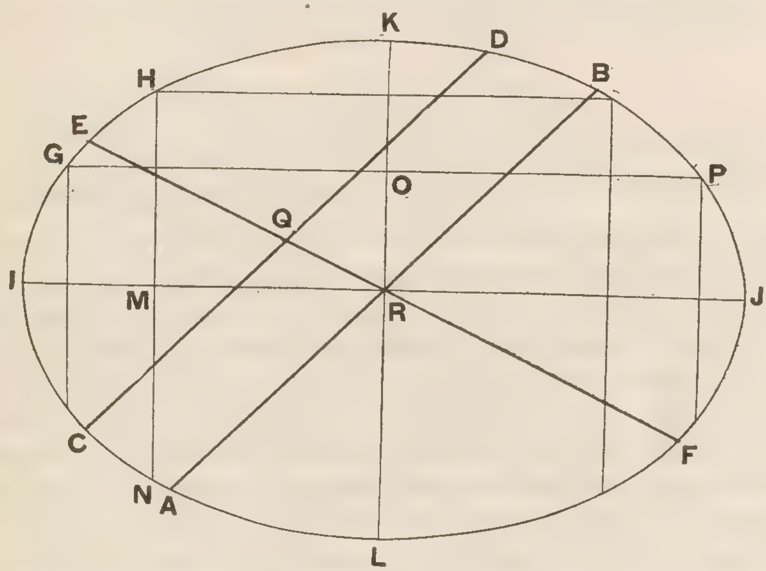


Fig. 9,366.—***General notes about ellipses.*** If from any points G, H, in the curve of an ellipse, lines parallel to the major axis I J, be drawn, or to the minor axis K L, be drawn, and the distance M N, be made equal to M H, or O P, be made equal to O G, other points, N, P, in the elliptic curve are obtained. A line Q C, or Q D, drawn from any point Q, in a diameter E F, and parallel to a conjugate diameter A B, is called an ordinate. M H, O P, are also ordinates. The whole line C D, H N, or G P, is a double ordinate. Draw any cord C D, parallel to A B. Bisect A B, C D, at Q R. Then E F, drawn through Q R, is a *conjugate diameter* to A B. The minor axis is called "the conjugate axis," because of its relationship to the major axis. The major and minor axes are a *pair* of conjugate diameters.

Problem 45.—*To find the foci of an ellipse and then to draw the elliptic curve by means of intersecting arcs, the major axis P Q and minor axis T V being given.*

In fig. 9,637, with T, one end of the minor axis, as center and X Q, half the major axis as radius, describe arc *y*, cutting the major axis at F′, F″. These points are the required foci. Between F′ and X, mark any number of points 1, 2, 3, 4. With centers F′, F″, and radius P′, describe arcs *a*, *a*, *a*, *a*. With the same centers and radius Q 1, cut arcs *a*, *a*, *a*, *a*, at *b*, *b*, *b*, *b*. With each focus as center and radius P2, describe arcs, *c*, *c*, *c*, *c*. With the same centers and radius Q 2, cut these arcs at *d*, *d*, *d*, *d*. In the same way use points 3 and 4, to get *g*, *g*, *h*, *h*. Through points *b*, *d*, *g*, *h*, draw the curve of the ellipse. The points 1, 2, 3, 4 may be at any distance apart, but it is more convenient to let the divisions decrease in length toward F′. Do not make the arcs too long, as this causes confusion.

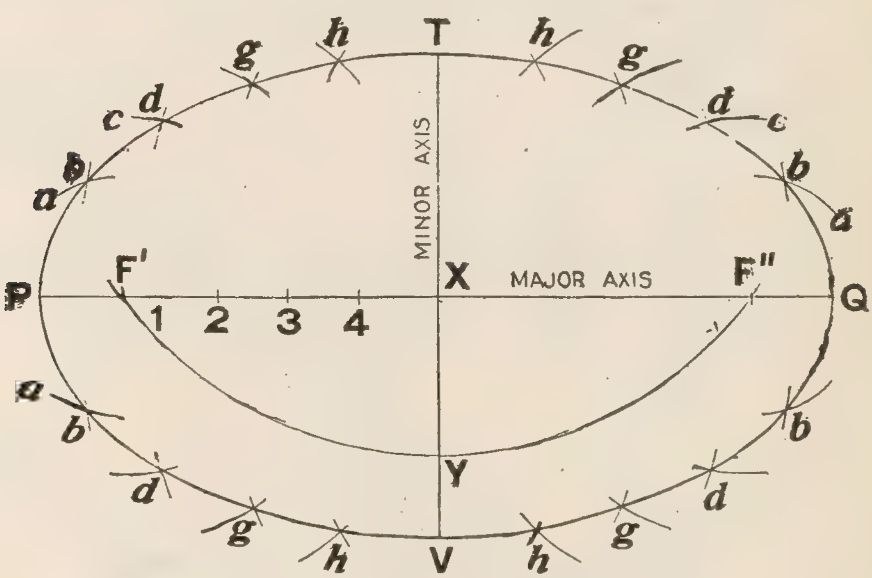


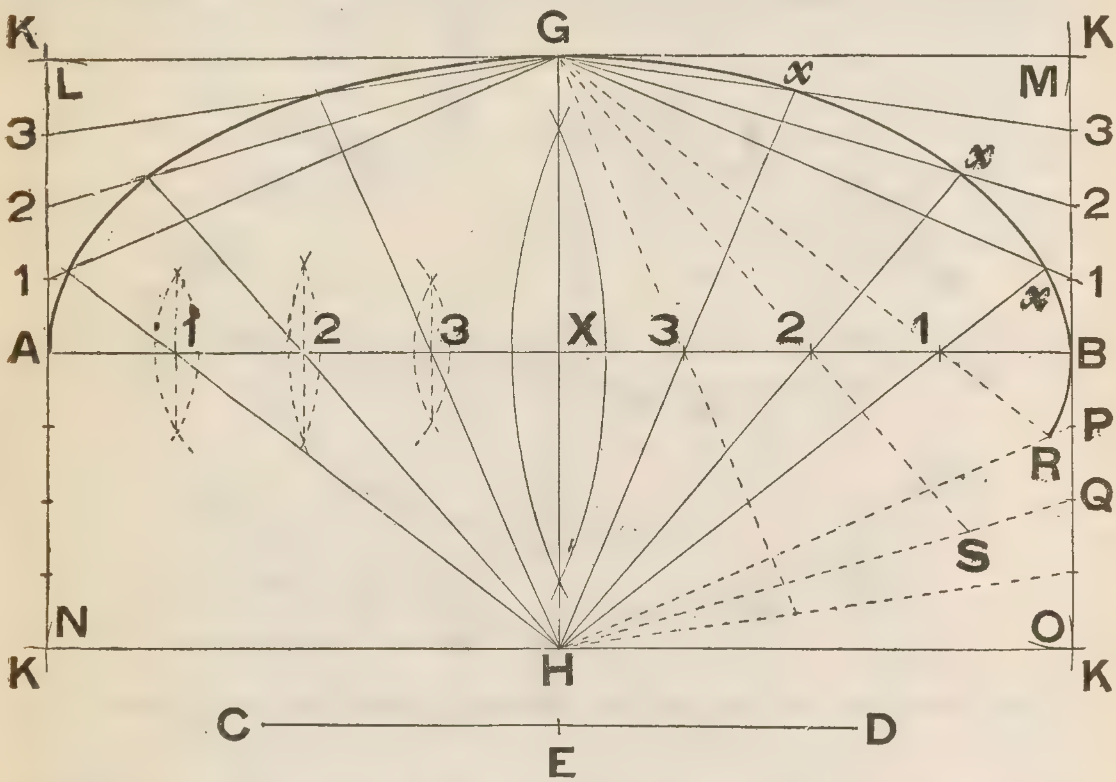
Fig. 9,367.—***Problem 46.***—The major axis and foci of an ellipse being given to find the minor axis.

Problem 46.—*The major axis and foci of an ellipse being given to find the minor axis.*

In fig. 9,367, bisect P Q, at X. With X P, or X Q, as radius and the foci as centers, strike arcs cutting at T and V. Join T V. Then T V, is the minor axis.

Problem 47.—Draw the curve of an ellipse by means of intersecting lines. The lengths of the major and minor axes AB, and CD, being given.

In fig. 9,369, bisect C D, at E. Bisect A B, at X, by a perpendicular. Make X G, X H, each equal to E C, or E D. With centers G, H, and radius X A, describe arcs at K, K,K,K. With centers A, B, and radius X G, cut these arcs at L, M, N, O. Join L M, M O, O N, N L. Divide A L, A N, B M, B O, A X, B X, each into the same number of equal parts, say four. Draw lines from G, to 1, 2, 3, on A L, B M. From H, through 1 (on A X), draw a line to meet 1 G, at *x*. Through 2, draw a line from H, to meet 2 G, at



Figs. 9,368 and 9,369.—***Problem 47.***—Draw the curve of an ellipse by means of intersecting lines.

x. Through 3, draw a line to meet 3 G, at *x*. In the same way get points *x*,*x*,*x*, on the other side. Also get similar points for the lower half of the ellipse, as shown by dotted lines at R and S. Through *x*,*x*,*x*, R, S, draw the curve of the ellipse. The divisions on A L, A X, may be unequal, provided those on A X, be proportional to those on A L. A French curve may be used for drawing the elliptic curve, through the points *x*,*x*,*x*. By this problem, an ellipse may be inscribed in any rectangle. By joining A G, G B, B H, H A, a rhombus is obtained. Therefore an ellipse can be circumscribed about a rhombus, or a rhombus can be inscribed in an ellipse.

Problem 48.*—The curve or portion of the curve of an ellipse being given, to find the center and the major or minor axes.*

In fig. 9,370, draw two parallel chords A B, C D. Bisect them at E and F, Through E, F, draw G H, which is a diameter. Bisect it at K, which is the center of the ellipse. With center K, and any convenient radius, describe the arc L M N. With centers L and M, and any radius, describe arcs cutting at O. From O, through K, draw P Q, which is the major axis. With center M and N, and any radius, describe arcs cutting at R. From R, through K, draw T S, which is the minor axis. Instead of describing arcs at O and R, L M, M N, may be joined and then the axes through K, parallel to L M, M N, drawn.

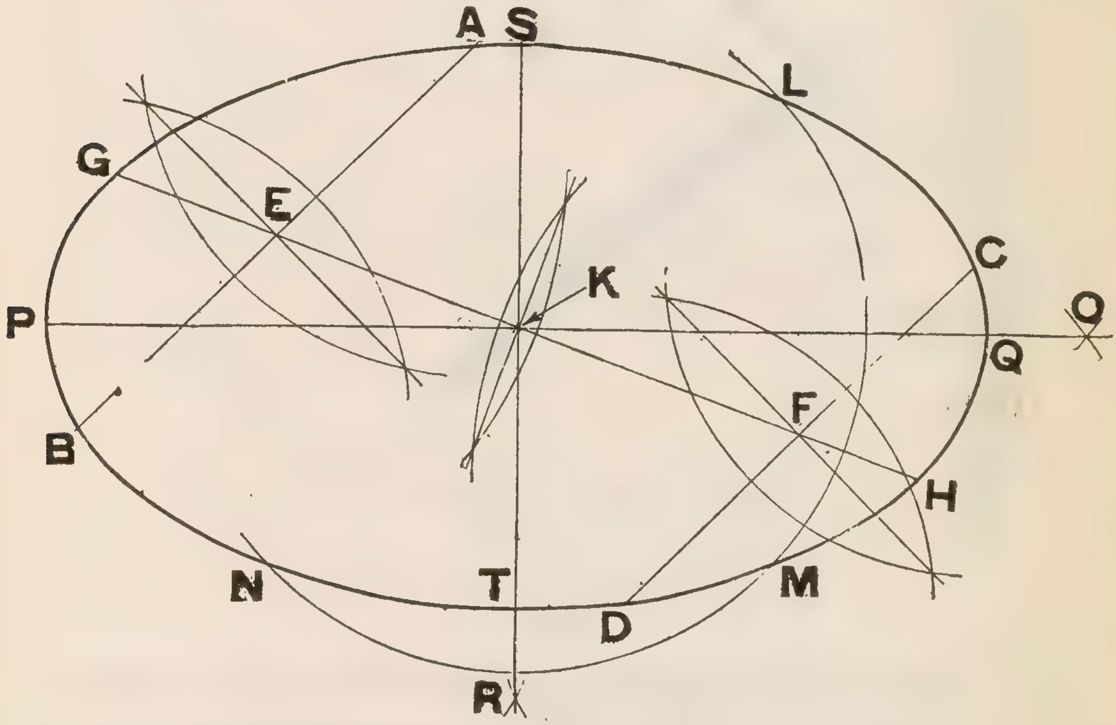


FIG. 9,370.—***Problem 48.***—The curve or portion of the curve of an ellipse being given, to find the center and the major or minor axes.

For convenience, the given ellipse may be drawn with a piece of thread as shown in fig. 9,364. If a small portion of the curve be given, the chords A B, C D, must be drawn closer together, If only one end of G H, meet the curve, draw another pair of parallel chords, and get another diameter, then the intersection of the two diameters gives the center. The portion of the curve given should contain at least one end of each axis.

NOTE.—***To draw an ellipse*** when the foci and one point in the curve are given. Draw a line of indefinite length through the foci. Draw a line from each focus to the given point. The sum of these two lines gives the length of the major axis. With half the major axis at radius, and the foci as centers, describe arcs intersecting at points, which give the ends of the minor axis. Obtain the curve of the ellipse.

Problem 49.*—At any point A, in the curve of an ellipse, to draw a normal; and through any point B in the curve to draw a tangent.*

In fig. 9,371, draw the ellipse with a piece of thread. From each focus, draw a line through A, to D, and C. Bisect angle D A C, by A E. The line A E, is the required normal (or perpendicular). From the foci draw lines to B. Produce one of the lines, say to G. Bisect the angle G B F″, by H K. Then the line H K is the required tangent. The normal may also be obtained by bisecting the angle F′ A F″. To draw a normal at either

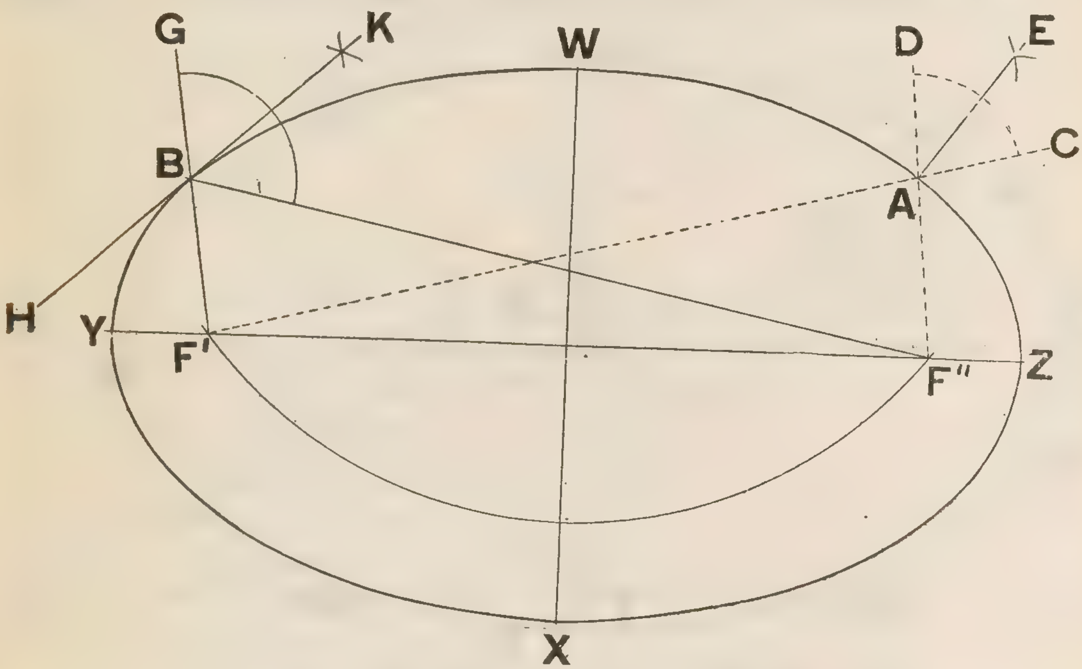


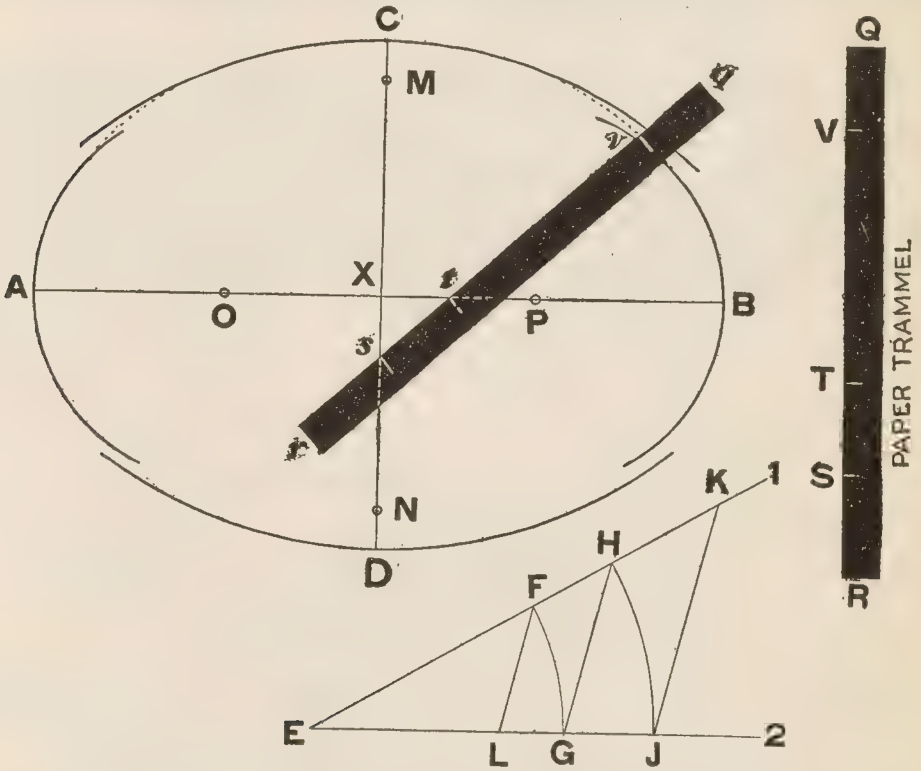
FIG. 9,371.—***Problem 49.***—At any point in the curve of an ellipse to draw a normal; and through any point in the curve to draw a tangent.

extremity of the major or minor axis, simply produce the axis. A tangent at either extremity of the major or minor axes must be drawn at right angles to the axis.

NOTE.—***To draw tangential lines to an ellipse from a given point outside the curve.*** Call given point 1, and place it in any position with regard to ellipse. With 1, as center and the distance to the nearer focus, as radius, describe about half of a circle cutting the ellipse in two places. With the further focus as center and the major axis as radius, cut the arc in points 2 and 3. From points 2 and 3, draw lines to the further focus. These lines cut the ellipse in two points. Call these points 4 and 5; they are the required points of contact. Draw two lines from the given point 1, through points 4 and 5; and these lines are the required tangents.

Problem 50.—*To get the curve of an ellipse approximately with arcs of circles, and by the use of a paper trammel.*

In fig. 9,372, the lines A B, C D, are the major and minor axes. Draw E 1, E 2, at any angle. Make E G = X C, and E H = X A. Join G H. With center E, and radii E G, E H, strike the arcs G F, H J. Draw F L, J K, parallel to G H. Make D M, C N, equal to E K, and A O, B P, equal to E L. With centers N and M, and radius N C, describe arcs passing through C and D. With centers O, P, and radius O A, describe arcs at A and B. These four arcs give approximately parts of the ellipse. On one edge of a straight



Figs. 9,372 to 9,734.—***Problem 50.***—To get the curve of an ellipse approximately with arcs of circles, and by the use of a paper trammel. ***This method applies*** only when the minor axis is more than about $^3/_5$ of the major axis. In making a narrow ellipse M and N will fall outside the ellipse.

slip of paper Q R, set off V S, equal to A X, and V T, equal to C X. Then use Q R, as a trammel. Adjust the trammel Q R, in such a manner, that

NOTE.—***To describe an ellipse,*** having one diameter given, similar to any given ellipse. In two similar ellipses, any two conjugate diameters of one ellipse have the same proportion to each other as the corresponding conjugate diameters of the other ellipse have to each other. Therefore find a fourth proportional to the given diameter, and the two diameters of the given ellipse. This fourth proportional gives the length of the other diameter of the required ellipse. Place the two diameters bisecting each other, and at the required angle and describe the ellipse.

point *t*, rests somewhere on the major axis; and point *s*, on the minor axis. Wherever point *v*, comes, will be a point situated in the curve of the ellipse. Mark several points as at *w*, and through these points draw curves connecting the arcs. E L, is a third proportional less, and E K, is a third proportional greater, to the lines E G, E H. A French curve may be used to connect the arcs through the points at *w*. The entire curve can be drawn by means of points obtained with a trammel. When an ellipse has a short minor axis, the points M and N, fall outside the ellipse, on the minor axis produced. This method is exceedingly useful when representing circles in perspective, and also in mechanical drawing when describing ellipses.

CHAPTER 145

Mensuration

Mensuration.—Briefly, by definition, mensuration is *the act, art, or process of measuring.*

It is that branch of mathematics that has to do with finding the length of lines, the area of surfaces, and the volume of solids. Accordingly the problems which follow will be divided into three groups, as:

1. Measurement of lines.
   a. One dimension, *length*
2. Measurement of surfaces (*areas*).
   a. Two dimensions, *length* and *breadth*
3. Measurement of solids (*volumes*).
   a. Three dimensions. *length, breadth,* and *thickness*

1. Measurement of Lines
(length)

Problem 1.—To find the length of any side of a right triangle, the other two sides being given.

Rule.—*Length of hypotenuse equals square root of the sum of*

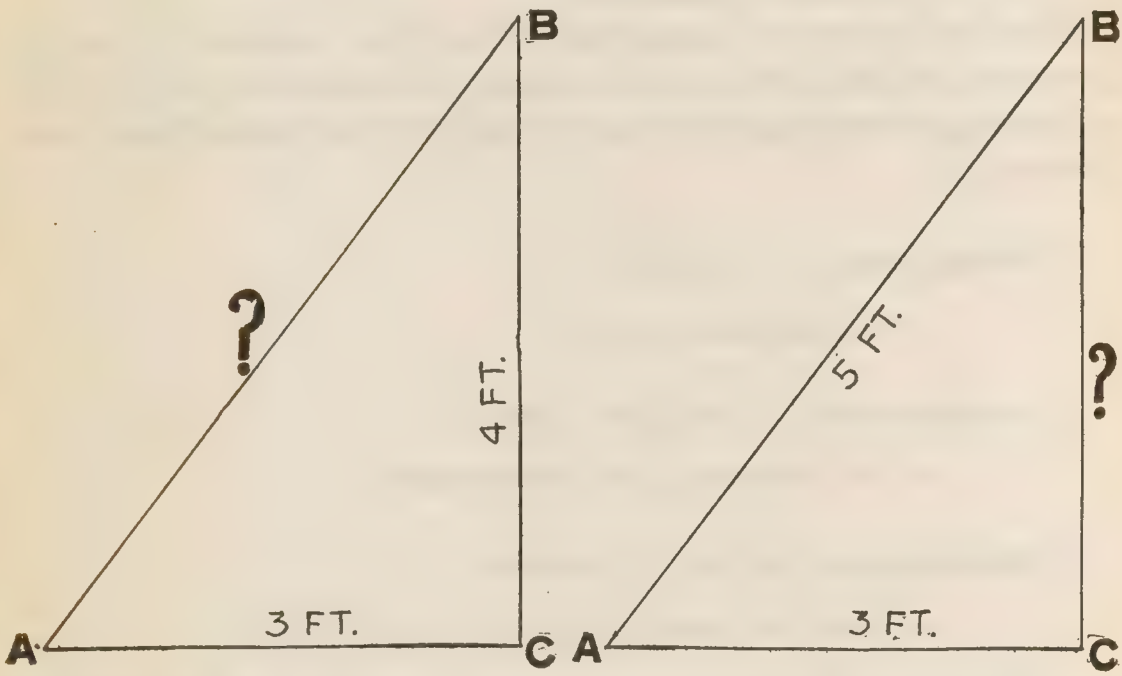
the squares of the two legs; length of either leg equals square root of the difference of the square of the hypotenuse and the square of the other leg.

Example.—The two legs of a right triangle measure 3 and 4 ft.; find length of hypotenuse. If the length of hypotenuse and one leg be 5 and 4 ft. respectively, what is the length of the other leg.

In fig. 9,375

$$AB = \sqrt{3^2 + 4^2} = \sqrt{25} = 5$$

In fig. 9,376 $BC = \sqrt{5^2 - 3^2} = \sqrt{25 - 9} = \sqrt{16} = 4.$



Figs. 9,375 and 9,376.—***Problem 1.*** *To find the length of any side of a right triangle.*

Problem 2.—To find length of circumference of a circle.

Rule.—*Multiply the diameter by* 3.1416.

Example.—What length of moulding strip is required for a circular window 5 ft. in diameter?

$$5 \times 3.1416 = 15.7 \text{ ft.}$$

As the mechanic does not ordinarily measure feet in tenths, the .7 should be reduced to inches; it corresponds to 8½ ins. from the table below. That is the length of moulding in 15 ft. 8½ ins.

Problem 3.—To find the length of an arc of a circle.

Rule.—*As* 360° *is to the number of degrees of the arc so is the length of the circumference to the length of the arc.*

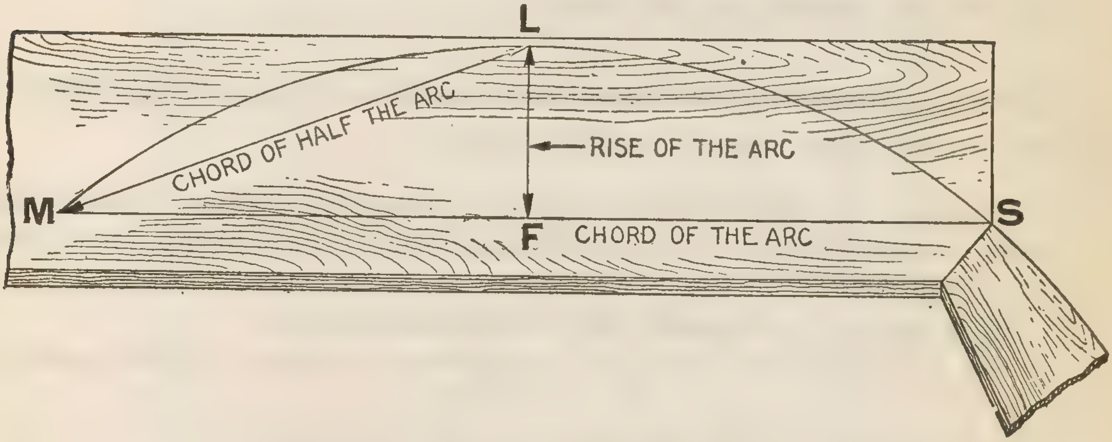


Fig. 9,377.—***Problem 4.*** *To find width of board required for plate form of circular pattern.*

Decimals of a Foot and Inches

Inch	0"	1"	2"	3"	4"	5"	6"	7"	8"	9"	10"	11"
0	.0	.0833	.1677	.2500	.3333	.4167	.5000	.5833	.6667	.7500	.8333	.9167
1-16	.0052	.0885	.1719	.2552	.3385	.4219	.5052	.5885	.6719	.7552	.8385	.9219
1-8	.0104	.0937	.1771	2604	.3437	.4271	.5104	.5937	.6771	.7604	.8437	.9271
3-16	.0156	.0990	.1823	.2656	.3490	.4323	.5156	.5990	.6823	.7656	.8490	9323
1-4	.0208	.1042	.1875	.2708	.3542	.4375	.5208	.6042	.6875	.7708	.8542	.9375
5-16	0260	1094	.1927	.2760	.3594	.4427	.5260	.6094	.6927	.7760	.8594	.9427
3-8	0312	.1146	.1979	2812	.3646	.4479	.5312	.6146	.6979	7812	.8646	.9479
7-16	.0365	.1198	.2031	.2865	.3698	.4531	.5365	.6198	.7031	.7865	.8698	9531
1-2	.0417	.1250	2083	.2917	.3750	.4583	.5417	.6250	.7083	.7917	.8750	.9583
9-16	.0469	.1302	.2135	.2969	.3802	.4635	.5469	.6302	.7135	.7969	8802	.9635
5-8	.0521	.1354	.2188	3021	.3854	.4688	.5521	.6354	.7188	.8021	.8854	9688
11-16	.0573	.1406	.2240	.3073	.3906	.4740	.5573	.6406	.7240	.8073	.8906	.9740
3-4	.0625	.1458	.2292	3125	.3958	.4792	.5625	.6458	.7292	8125	.8958	.9792
13-16	.0677	.1510	.2344	.3177	4010	.4844	.5677	6510	.7344	.8177	.9010	.9844
7-8	.0729	.1562	.2396	.3229	4062	4896	5729	.6562	7396	.8229	.9062	.9896
15-16	.0781	.1615	.2448	.3281	4115	.4948	.5781	6615	7448	.8281	9115	.9948

Example.—If the circumference of a circle be 6 feet, what is the length of 60° arc?

Let X = length of the arc, solving for X.

$$360 : 60 = 6 : X = \frac{60 \times 6}{360} = \frac{360}{360} = \mathbf{1\ ft.}$$

Problem 4.—To find the rise of an arc.

Rule 1.—*The rise of an arc is equal to the square of the chord of half the arc divided by the diameter.*

Rule 2.—*Length of the chord subtending an angle at the center is equal to twice the sine of half the angle.*

Example.—A circular pattern 10 ft. in diam. has six plate forms. Find width of board required for these forms allowing 3 ins. margin for joints as in fig. 9,377.

Each plate will subtend an angel of 360 ÷ 6 = 60°
The "chord of half the arc" (mentioned in rule 1) will subtend 60 ÷ 2 = 30°.

Applying rule 2, "half the angle" = 30° ÷ 2 = 15°.

From table of "trigonometrical functions" (page **2,826**), sine of 15° = .259, which with radius of 5 ft., becomes

$$\sin 15° \text{ (on 10-ft. circle)} = 5 \times .259 = 1.295$$

Applying rule 2 length of chord ML, = 2 × 1.295 = 2.59

Applying rule 1 rise of arc MS, = 2.59^2 ÷ 10 = .671 ft. or 8½ ins. (approx.)

Add to this 3 ins. margin for joints and obtain

width of board 8⅛ + 3 = 11⅛. Use 12 in. board

2. Measurement of Surfaces

(areas)

Problem 5.—To find the area of a square.

Rule.—*Multiply the base by the height.*

Example.—What is the area of a square whose side is 5 ft. as in fig. 9,378?

$$5 \times 5 = 25 \text{ sq. ft.}$$

Problem 6.—To find the area of a rectangle.

Rule.—*Multiply the base by the height (i. e., width by length).*

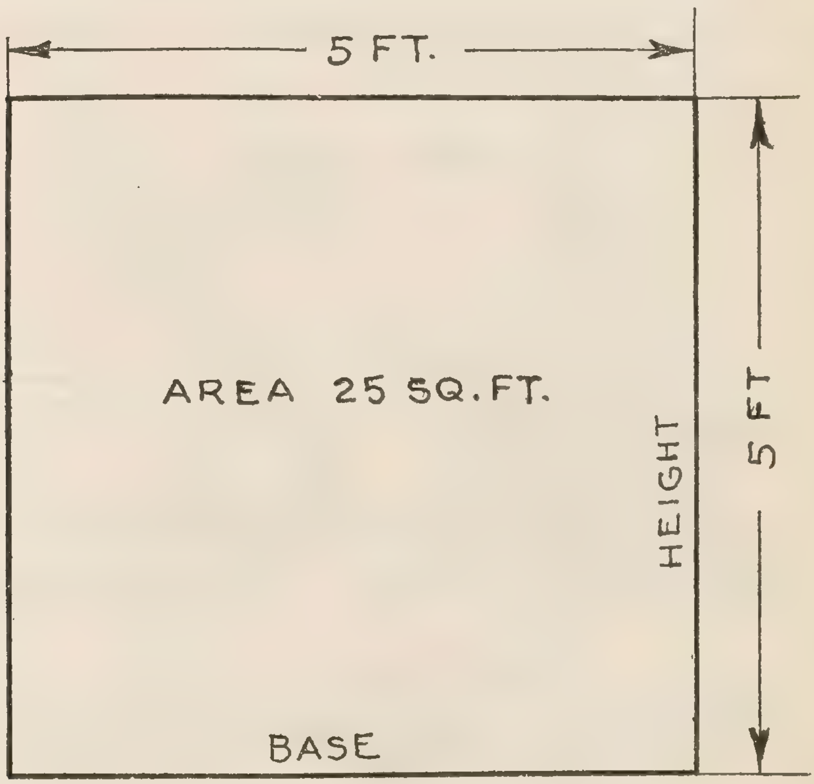


FIG. 9,378.—***Problem 5.*** *Area of square.*

Example.—What is the area of a rectangle 5 ft. wide and 12 ft. long, as in fig. 9,379?

$$5 \times 12 = 60 \text{ sq. ft.}$$

Problem 7.—To find the area of a parallelogram.

Rule.—*Multiply base by perpendicular height.*

Example.—What is the area of a parallelogram 2 ft. wide and 10 ft. long?

$$2 \times 10 = 20 \text{ sq. ft.}$$

Problem 8.—To find the area of a triangle.

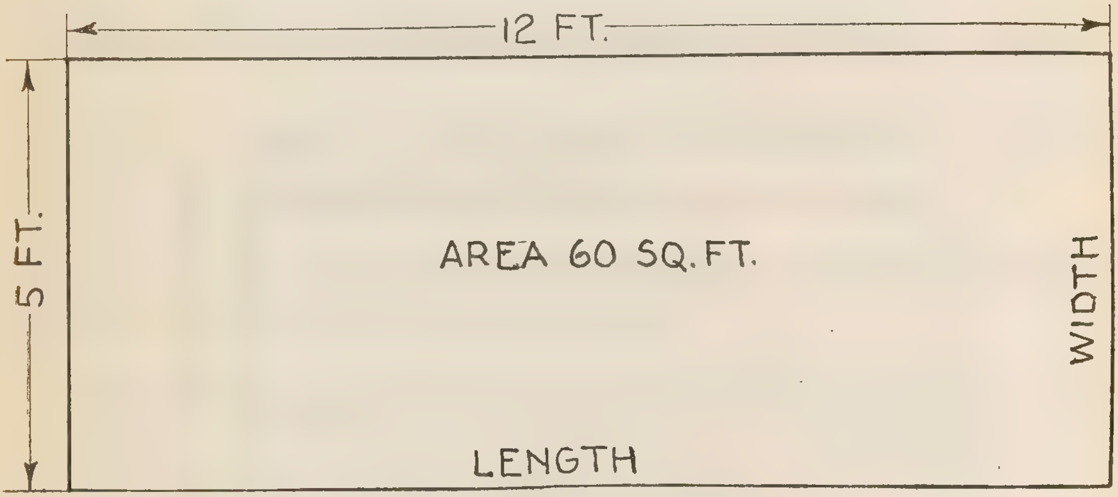


FIG. 9,379.—***Problem 6.*** *Area of rectangle.*

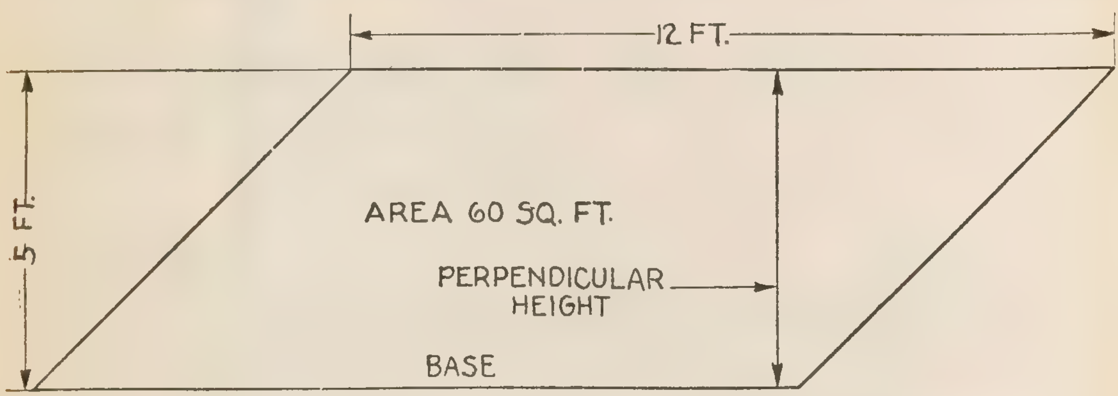


FIG. 9,380.—***Problem 7.*** *Area of parallelogram.*

Rule.—*Multiply the base by half the altitude.*

Example.—How many sq. ft. of sheet tin are required to cover a church steeple having four triangular sides, measuring 12 ft. (base) × 30 ft. (altitude as in fig. 9,381)?

$$\tfrac{1}{2} \text{ of altitude} = 15 \text{ ft.}$$

$$\text{area of one side} = 12 \times 15 = 180 \text{ sq. ft.}$$

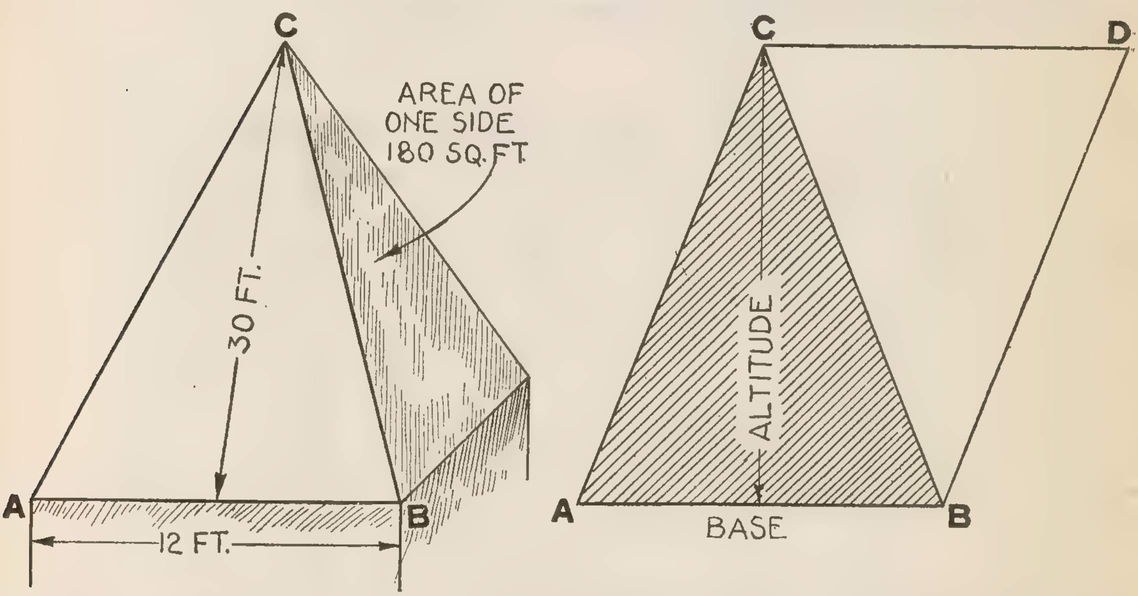
Total area (four sides) $4 \times 180 = 720$ sq. ft.

Problem 9.—To find the area of a trapezoid.

Rule.—*Multiply one-half the sum of the two parallel sides by the perpendicular distance between them.*

Example.—What is the area of the trapezoid shown in fig. 9,383?

Here LA and FR, are the parallel sides and MS, the perpendicular dis-



FIGS. 9,381 and 9,382.—***Problem 8.*** *Area of triangle.* An inspection of fig. 9,382 will show that area of triangle = base × ½ altitude because constructing a parallelogram ABCD, it is made up of two equal triangles and its area = base × altitude. Hence ½ altitude is taken in finding area of a triangle.

tance between them. Applying rule

$$\begin{aligned} \text{area} &= \tfrac{1}{2}(LA + FR) \times MS \\ &= \tfrac{1}{2}(8 + 12) \times 6 = 60 \text{ sq. ft.} \end{aligned}$$

Problem 10.—To find the area of a trapezium.

Rule.—*Draw a diagonal, dividing figure into triangles; measure diagonal and altitudes and find area of the triangles.*

Example.—What is the area of the trapezium shown in fig. 9,384, for the dimensions given? Draw diagonal LR, and altitudes AM and FS.

$$\begin{aligned} \text{area triangle ALR} &= 12 \times {}^6/_2 = 36 \text{ sq. ft.} \\ \text{area triangle LRF} &= 12 \times {}^9/_2 = 54 \text{ sq. ft.} \\ \hline \text{area trapezium LARF} &= \ldots\ldots\ldots\ldots 90 \text{ sq. ft.} \end{aligned}$$

Problem 11.—To find the area of any irregular polygon.

Rule.—*Draw diagonal dividing the figures into triangles and find the sum of the areas of these triangles.*

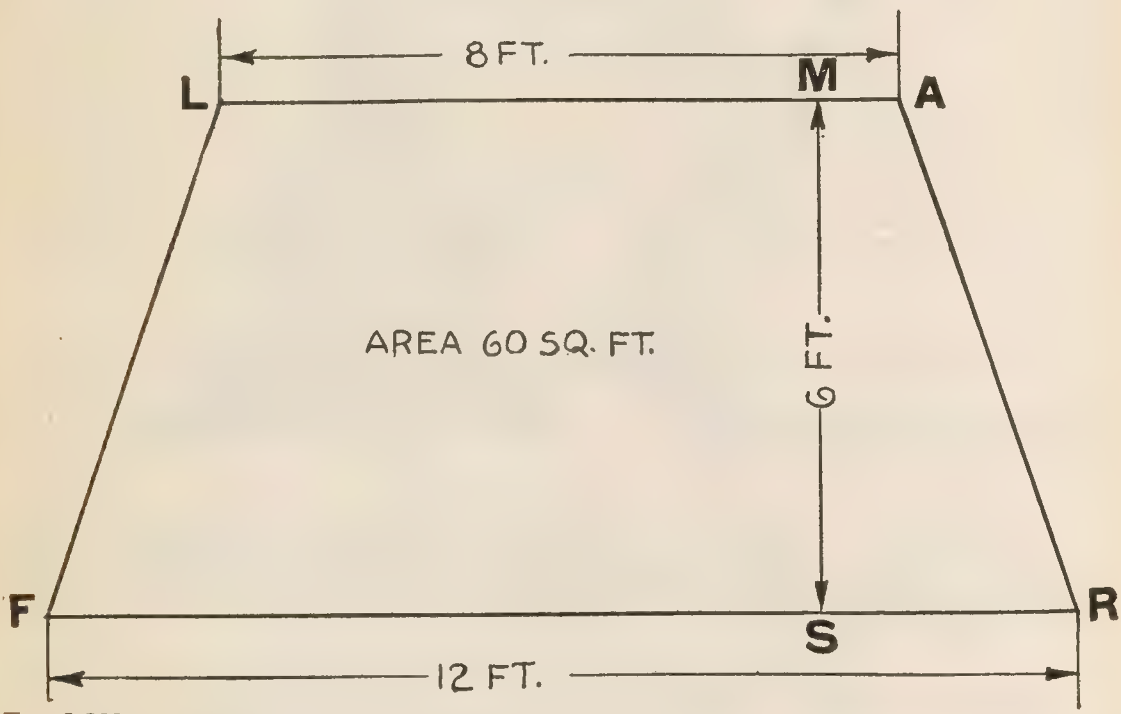


FIG. 9,383.—***Problem 9.*** *Area of trapezoid.*

Problem 12.—To find the area of any regular polygon when length of side only is given.

Rule.—*Multiply the square of the sides by the figure for "area, side = 1" opposite to the polygon in the table following:*

Table of Regular Polygons

Number of sides	3	4	5	6	7	8	9	10	11	12
Area when side =1.........	.433	1.	1.721	2.598	3.634	4.828	6.181	7.694	9.366	11.196

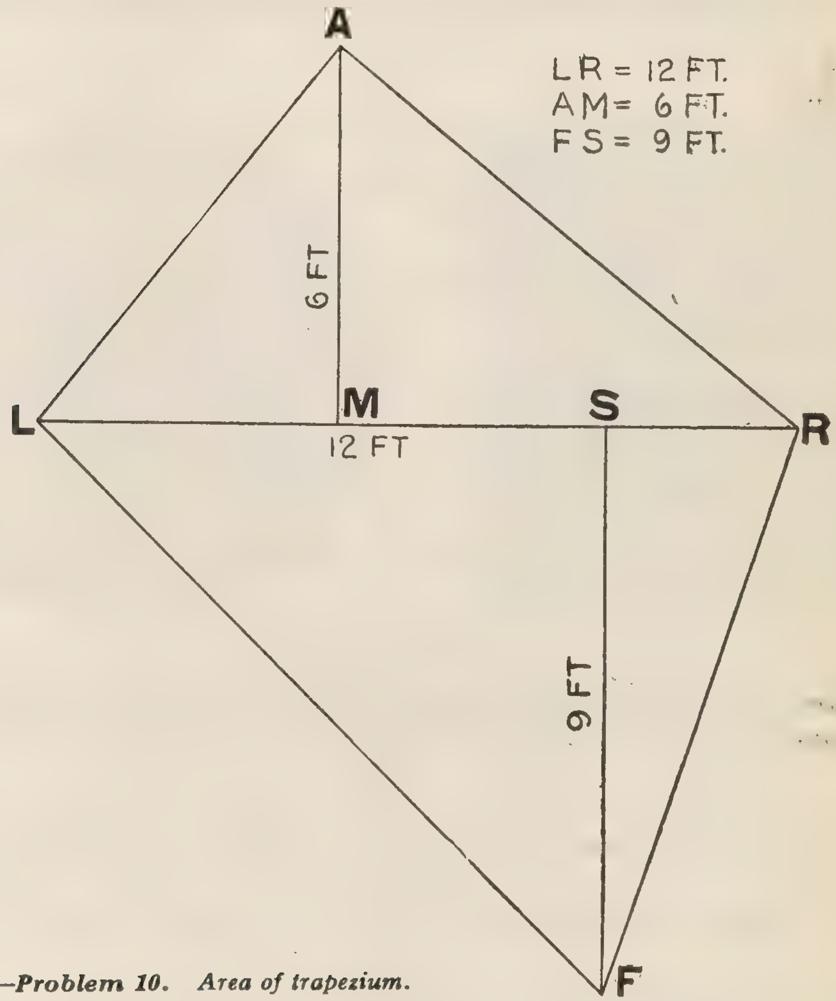


FIG. 9,384.—*Problem 10. Area of trapezium.*

Example.—What is the area of an octagon (8-sided polygon) whose sides measure 4 ft.

In the above table under 8, find 4.828. Multiply this by the square of one side.

$$4.828 \times 4^2 = 77.25 \text{ sq. ft.}$$

Problem 13.—To find the area of a circle.

Rule.—*Multiply square of diameter by .7854.*

Example.—What is the area of a circle 10 ft. in diameter?

$$10^2 \times .7854 = 78.54 \text{ sq. ft.}$$

Fig. 9,385 shows why the decimal .7854 is used in finding the area of a circle.

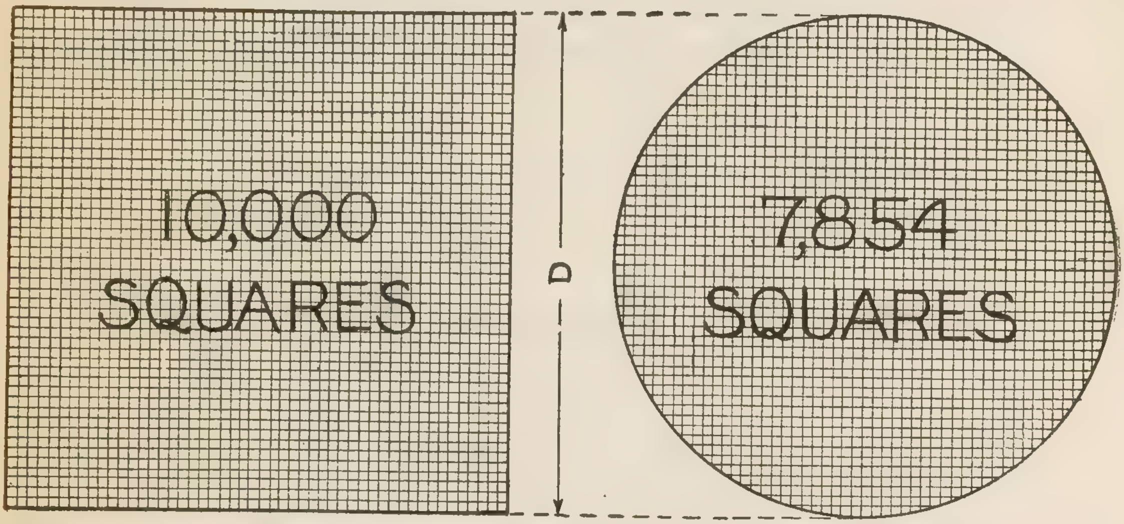


FIG. 9,385.—Diagram illustrating why the decimal .7854 is used to find the area of a circle. If the square be divided into 10,000 parts or small squares, a circle having a diameter D, equal to a side of the large square will contain 7,854 small squares, hence, if the area of the large square be 1 sq. in., then the area of the circle will be 7854 ÷ 10,000 or .7854 sq. ins., that is, area of the circle = .7854 × D × D = .7854 × 1 × 1 = .7854 sq. ins.

Problem 14.—To find the area of a sector of a circle.

Rule.—*Multiply the arc of the sector by half the radius.*

Example.—How much tin is required to cover a 60° section of a 10 foot circular deck?

$$\text{length of } 60^\circ \text{ arc} = \frac{60}{360} \text{ of } 3.1416 \times 10 = 5.24 \text{ ft.}$$

The reason for the above operation should be apparent without any explanation.

Applying rule

tin required for 60° sector = 5.24 × ½ of 5 = 13.1 sq. ft.

Problem 15.—To find the area of a segment of a circle.

Rule.—*Find the area of the sector which has the same arc and also the area of the triangle formed by the radii and chord; take the sum of these areas if the segment be greater than* 180°; *take the difference if less.*

Problem 16.—To find the area of a ring.

Rule.—*Take the difference between the areas of the two circles.*

Problem 17.—To find the area of an ellipse.

Rule.—*Multiply the product of the two diameters by* .7854.

Example.—What is the area of an ellipse where two diameters are 10 and 6 inches?

$$10 \times 6 \times .7854 = 47.12 \text{ sq. ins.}$$

Problem 18.—To find the circular area of a cylinder.

Rule.—*Multiply* 3.1416 *by the diameter and by the height.*

Example.—How many sq. ft. of lumber are required for the sides of a cylindrical tank 8 ft. in diameter and 12 ft. high; how many pieces 4″ × 12′ will be required?

cylindr.cal surface 3.1416 × 8 × 12 = 302 sq. ft.

circumference of tank = 3.1416 × 8 = 25.1 ft.

Number 4″ × 12′ pieces 25.1 ÷ $^4/_{12}$ = 25.1 × 3 = 75.3, say 76.

Problem 19.—To find the slant area of a cone.

CYLINDRICAL VESSELS, TANKS, CISTERNS, ETC.

Diameter in Feet and Inches, Area in Square Feet, and U. S. Gallons Capacity for One Foot in Depth.

$$1 \text{ gallon} = 231 \text{ cubic inches} = \frac{1 \text{ cubic foot}}{7.4805} = 0.13368 \text{ cubic feet.}$$

Diam.	Area.	Gals.	Diam.	Area.	Gals.	Diam.	Area.	Gals.
Ft. In.	Sq. ft.	1 foot depth.	Ft. In.	Sq. ft.	1 foot depth.	Ft. In.	Sq. ft.	1 foot depth.
1	.785	5.87	5 8	25.22	188.66	19	283.53	2120.9
1 1	.922	6.89	5 9	25.97	194.25	19 3	291.04	2177.1
1 2	1.069	8.00	5 10	26.73	199.92	19 6	298.65	2234.0
1 3	1.227	9.18	5 11	27.49	205.67	19 9	306.35	2291.7
1 4	1.396	10.44	6	28.27	211.51	20	314.16	2350.1
1 5	1.576	11.79	6 3	30.68	229.50	20 3	322.06	2409.2
1 6	1.767	13.22	6 6	33.18	248.23	20 6	330.06	2469.1
1 7	1.969	14.73	6 9	35.78	267.69	20 9	338.16	2529.6
1 8	2.182	16.32	7	38.48	287.88	21	346.36	2591.0
1 9	2.405	17.99	7 3	41.28	308.81	21 3	354.66	2653.0
1 10	2.640	19.75	7 6	44.18	330.48	21 6	363.05	2715.8
1 11	2.885	21.58	7 9	47.17	352.88	21 9	371.54	2779.3
2	3.142	23.50	8	50.27	376.01	22	380.13	2843.6
2 1	3.409	25.50	8 3	53.46	399.88	22 3	388.82	2908.6
2 2	3.687	27.58	8 6	56.75	424.48	22 6	397.61	2974.3
2 3	3.976	29.74	8 9	60.13	449.82	22 9	406.49	3040.8
2 4	4.276	31.99	9	63.62	475.89	23	415.48	3108.0
2 5	4.587	34.31	9 3	67.20	502.70	23 3	424.56	3175.9
2 6	4.909	36.72	9 6	70.88	530.24	23 6	433.74	3244.6
2 7	5.241	39.21	9 9	74.66	558.51	23 9	443.01	3314.0
2 8	5.585	41.78	10	78.54	587.52	24	452.39	3384.1
2 9	5.940	44.43	10 3	82.52	617.26	24 3	461.86	3455.0
2 10	6.305	47.16	10 6	86.59	647.74	24 6	471.44	3526.6
2 11	6.681	49.98	10 9	90.76	678.95	24 9	481.11	3598.9
3	7.069	52.88	11	95.03	710.90	25	490.87	3672.0
3 1	7.467	55.86	11 3	99.40	743.58	25 3	500.74	3745.8
3 2	7.876	58.92	11 6	103.87	776.99	25 6	510.71	3820.3
3 3	8.296	62.06	11 9	108.43	811.14	25 9	520.77	3895.6
3 4	8.727	65.28	12	113.10	846.03	26	530.93	3971.6
3 5	9.168	68.58	12 3	117.86	881.65	26 3	541.19	4048.4
3 6	9.621	71.97	12 6	122.72	918.00	26 6	551.55	4125.9
3 7	10.085	75.44	12 9	127.68	955.09	26 9	562.00	4204.1
3 8	10.559	78.99	13	132.73	992.91	27	572.56	4283.0
3 9	11.045	82.62	13 3	137.89	1031.5	27 3	583.21	4362.7
3 10	11.541	86.33	13 6	143.14	1070.8	27 6	593.96	4443.1
3 11	12.048	90.13	13 9	148.49	1110.8	27 9	604.81	4524.3
4	12.566	94.00	14	153.94	1151.5	28	615.75	4606.2
4 1	13.095	97.96	14 3	159.48	1193.0	28 3	626.80	4688.8
4 2	13.635	102.00	14 6	165.13	1235.3	28 6	637.94	4772.1
4 3	14.186	106.12	14 9	170.87	1278.2	28 9	649.18	4856.2
4 4	14.748	110.32	15	176.71	1321.9	29	660.52	4941.0
4 5	15.321	114.61	15 3	182.65	1366.4	29 3	671.96	5026.6
4 6	15.90	118.97	15 6	188.69	1411.5	29 6	683.49	5112.9
4 7	16.50	123.42	15 9	194.83	1457.4	29 9	695.13	5199.9
4 8	17.10	127.95	16	201.06	1504.1	30	706.86	5287.7
4 9	17.72	132.56	16 3	207.39	1551.4	30 3	718.69	5376.2
4 10	18.35	137.25	16 6	213.82	1599.5	30 6	730.62	5465.4
4 11	18.99	142.02	16 9	220.35	1648.4	30 9	742.64	5555.4
5	19.63	146.88	17	226.98	1697.9	31	754.77	5646.1
5 1	20.29	151.82	17 3	233.71	1748.2	31 3	766.99	5737.5
5 2	20.97	156.83	17 6	240.53	1799.3	31 6	779.31	5829.7
5 3	21.65	161.93	17 9	247.45	1851.1	31 9	791.73	5922.6
5 4	22.34	167.12	18	254.47	1903.6	32	804.25	6016.2
5 5	23.04	172.38	18 3	261.59	1956.8	32 3	816.86	6110.6
5 6	23.76	177.72	18 6	268.80	2010.8	32 6	829.58	6205.7
5 7	24.48	183.15	18 9	276.12	2065.5	32 9	842.39	6301.5

Rule.—*Multiply* 3.1416 *by diameter of base and by one-half the slant height.*

Example.—A conical spire having a base 10 ft. diameter and altitude of 20 ft. is to be covered. Find area of surface to be covered.

In fig. 9,387, first find slant height, thus

$$\text{slant height} = \sqrt{5^2 + 20^2} = \sqrt{425} = 20.62 \text{ ft.}$$

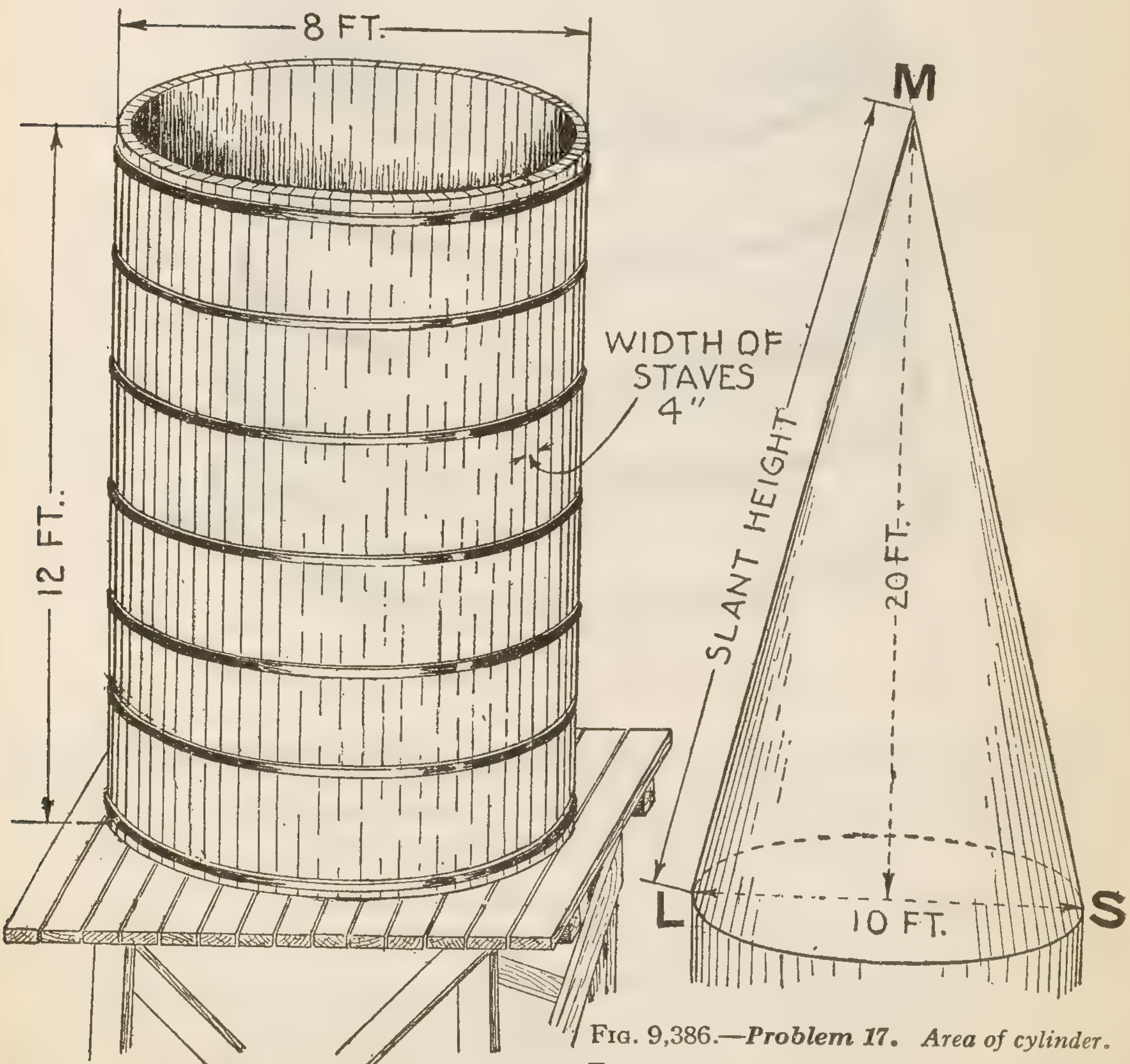


Fig. 9,386.—***Problem 17.*** *Area of cylinder.*
Fig. 9,387.—***Problem 18.*** *Area of cone.*

circumference of base = 3.1415 × 10 = 31.42 ft.
area of conical surface = 31.42 × ½ of 20.62 = 314 sq. ft.

Problem 20.—To find the (slant) area of the frustum of a cone.

Rule.—*Multiply half the slant height by the sum of the circumferences.*

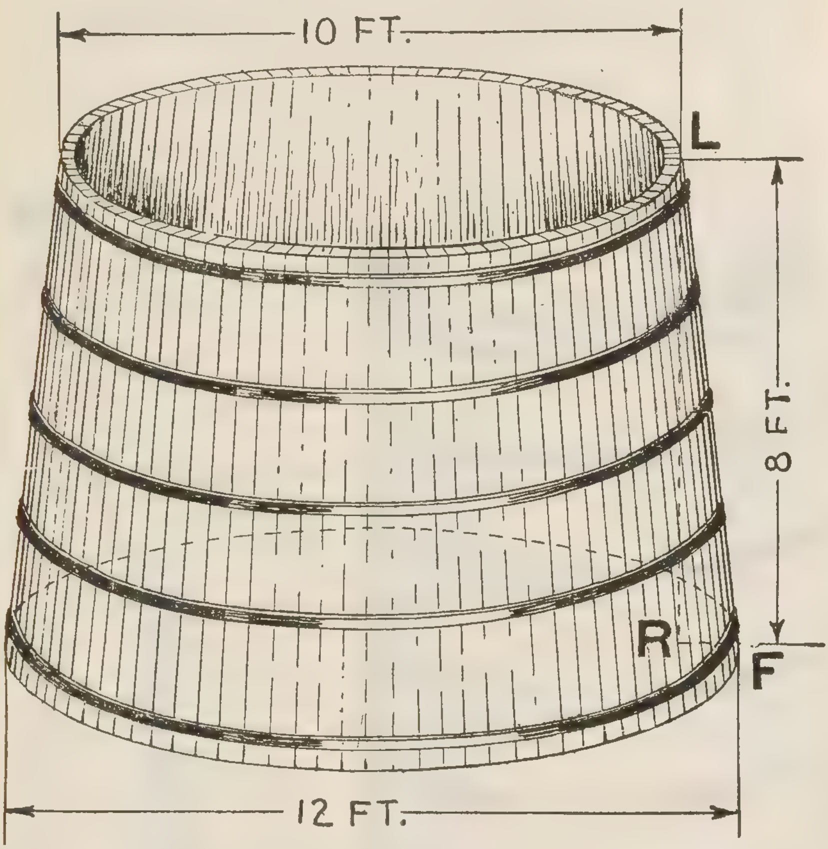


FIG. 9,388.—***Problem 19.*** *Area of frustum of a cone.* This is the shape of the ordinary wooden tank seen in wind mill towers. In the figure LR = height of tank. Since the difference between the two diameters is two feet, RF = 1 ft. Hence slant height or LF = $\sqrt{1^2 + 8^2}$ = 8.06.

Example.—A tank is 12 ft. in diameter at the base, 10 ft. at the top, and 8 ft. high. What is the area of the slant surface?

circumference 10 ft. circle = 3.1416 × 10 = 31.42 ft.
circumference 12 ft. circle = 3.1416 × 12 = 37.7 ft.
sum of circumferences = 69.1 ft.

$$\text{slant height} = \sqrt{1^2 + 8^2} = \sqrt{65} = 8.06$$

$$\text{slant surface} = \text{sum of circumferences} \times \tfrac{1}{2} \text{ slant height}$$

$$= 69.1 \times \tfrac{1}{2} \text{ of } 8.06 = 278.5 \text{ sq. ft.}$$

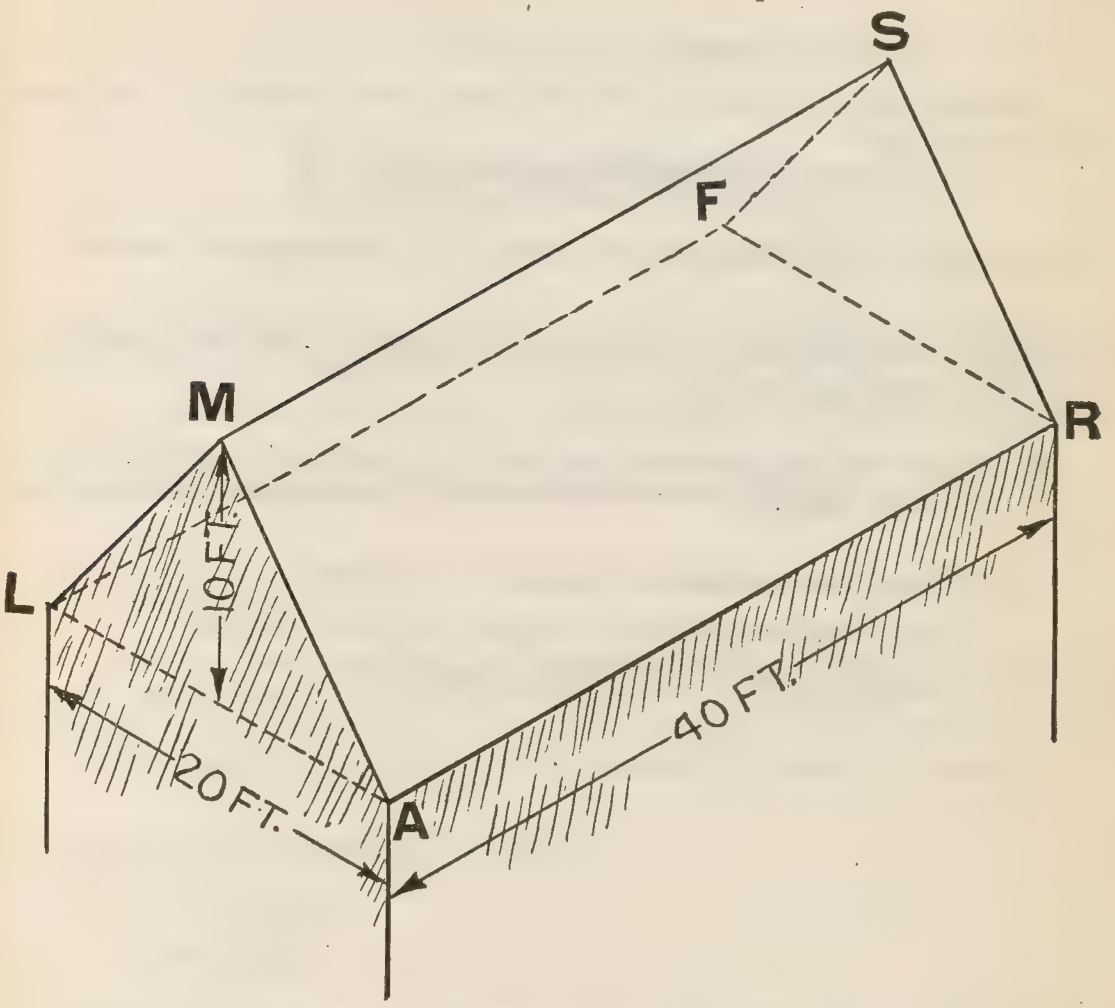


FIG. 9,389.—***Problem 20.*** *Volume of rectangular wedge.*

3. Measurement of Solids

(volumes)

Problem 21.—To find the volume of a rectangular solid.

Rule.—*Multiply length, breadth and thickness together.*

Example.—What is the volume of a timber $4'' \times 8'' \times 12'$? Before applying rule first reduce all dimensions to ft. thus,

$$4'' = {}^4/_{12} \text{ ft.} = \tfrac{1}{3} \text{ ft.}$$
$$8'' = \tfrac{2}{3} \text{ ft.}$$

$$\text{volume of timber} = \tfrac{1}{3} \times \tfrac{2}{3} \times 12 = 2.67 \text{ cu. ft.}$$

If the timber be a piece of oak weighing 48 lbs. per cu. ft. the total weight would be

$$48 \times 2.67 = 128 \text{ lbs.}$$

Problem 22.—To find the volume of a rectangular wedge.

Rule.—*Find the area of one of the triangular ends and multiply by distance between ends.*

Example.—A barn attic has the shape of a rectangular wedge. What volume storage capacity would there be for the proportions shown in fig. 9,389?

In the figure, the boundary of the attic is LARFMS.

$$\text{Area triangular end MLA} = 20 \times {}^{10}/_2 = 100 \text{ sq. ft.}$$

$$\text{volume of attic} = 100 \times 40 = 4{,}000 \text{ cu. ft.}$$

CHAPTER 146

Trigonometry

By definition trigonometry is *that branch of mathematics which treats of the relations of the sides and angles of triangles and applies them to other figures involving or containing triangles.*

Trigonometry is divided into two branches:

1. Plane.
2. Spherical.

Plane trigonometry deals with plane triangles, and spherical trigonometry with spherical triangles, the difference being shown in figs. 9,390 and 9,391. Evidently the kind of trigonometry the mechanic is interested in is plane trigonometry. Spherical trigonometry is useful in navigation.

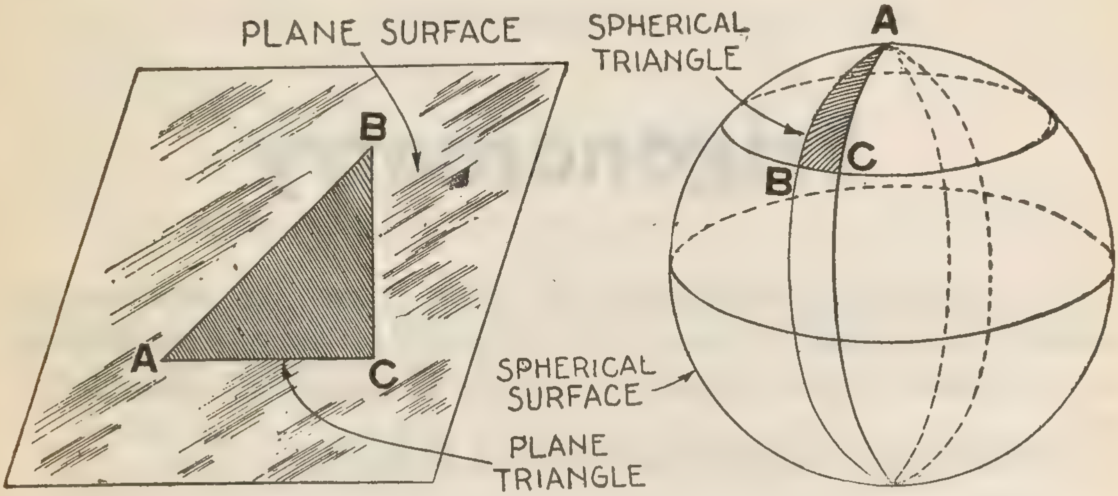
Every triangle has six parts:

1. Three angles.
2. Three sides.

When any three of these parts are given, provided one of them be a side, the other parts may be determined. The determination of the unknown parts is called the *solution of triangles*.

Measurement of Angles.—In trigonometry the arcs of circles are used to measure angles. The unit of measurement of angles is the *degree* (°). In this system of measurement, the circumfer-

ence of every circle is supposed to be divided into 360 equal parts, called degrees; thus, a degree is $^1/_{360}$ of the circumference of any circle. A degree is divided into 60 parts called minutes



FIGS. 9,390 and 9,391.—Plane and spherical triangles illustrating *plane* and *spherical* branches of trigonometry.

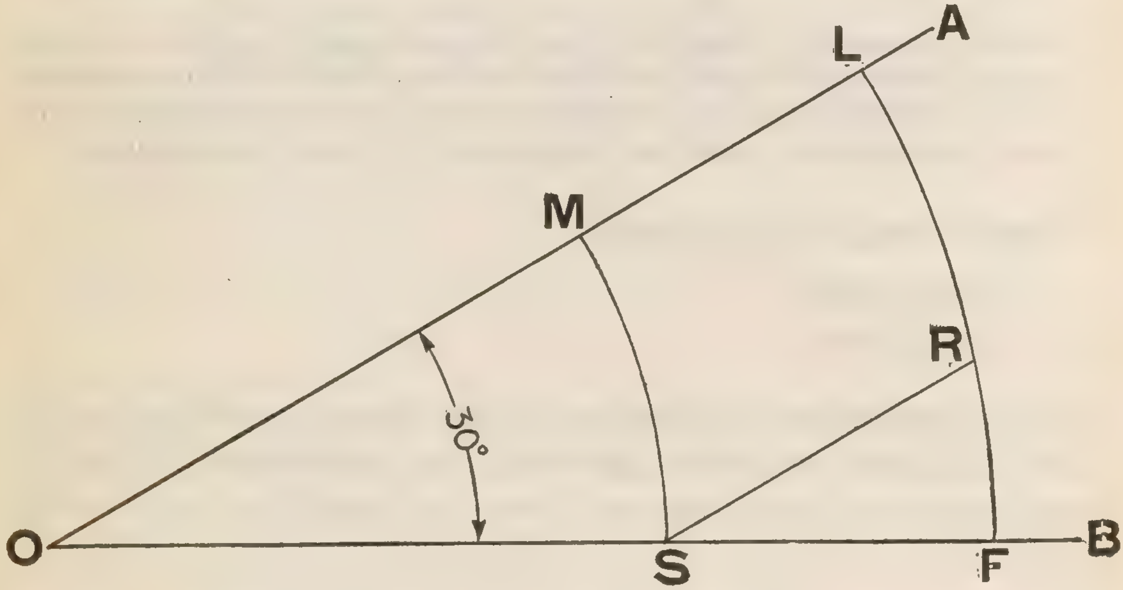


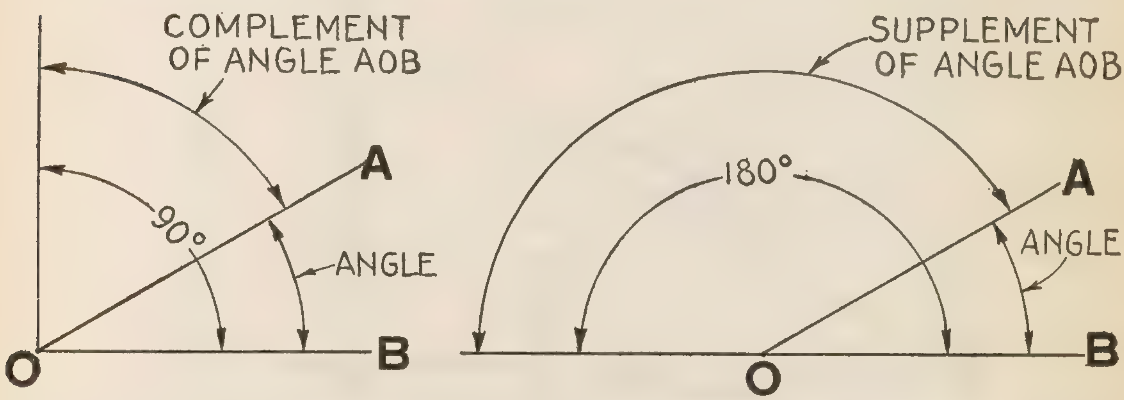
FIG. 9,392.—The length of a degree depends upon the diameter of the circle on which it is measured. Let the angle AOB, be measured on the arc MS, say 30°. Describe with longer radius another arc LF, and draw SR, parallel to MS, then LR, is approximately equal to MS, and LF, are in length $^{30}/_{360}$ of their respective circles, that is, each contains 30 degrees. Hence LR (approximately equal to MS) does not contain as many degrees as MS, and it follows that each degree on LF, is larger than on MS.

expressed by ($'$), and each minute is divided into 60 seconds, expressed by ($''$), so that the circumference of any circle contains 21,600 minutes or 1,296,000 seconds.

Evidently, then the length of a degree depends upon the diameter of the circle as shown in fig. 9,392.

The *complement* of an angle is the difference between 90° and the angle; the *supplement* of an angle is the difference between 180° and the angle. These terms are illustrated in figs. 9,393 and 9,394.

Trigonometrical Functions.—By definition, a function is a



FIGS. 9,393 and 9,394.—*Complement* and *supplement* of an angle.

quantity in mathematics so connected with another quantity that if any alteration be made in the latter there will be a consequent alteration in the former. The dependent quantity is said to be a function of the other. Thus, the circumference of the circle is a function of the diameter.

These functions may consist of:

1. Ratios.
2. Lines ("natural functions").

In the first instance they are defined by referring to a triangle made by drawing (as in fig. 9,395) a perpendicular from any point A, on one side of a given angle, MOS or θ, to the other side, as AB.

It will be noted that the triangle thus formed is a right triangle, that is, angle ABO = 90°. In this triangle the trigonometrical functions, expressed as ratios are as follows:

$$\textbf{\textit{Sine}} \text{ of the angle } \theta = \frac{AB}{AO} = \frac{\text{opposite side}}{\text{hypotenuse}}$$

$$\textbf{\textit{Cosine}} \text{ of the angle } \theta = \frac{OB}{OA} = \frac{\text{adjacent side}}{\text{hypotenuse}}$$

$$\textbf{\textit{Tangent}} \text{ of the angle } \theta = \frac{AB}{OB} = \frac{\text{opposite side}}{\text{adjacent side}}$$

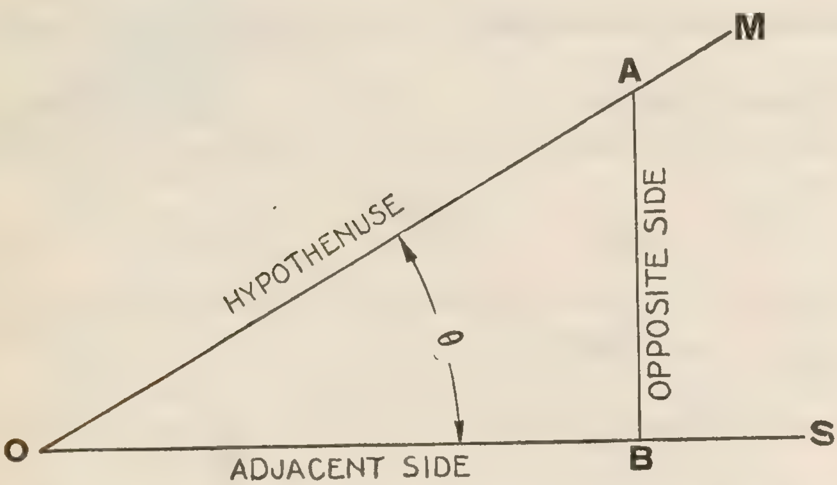


Fig. 9,395.—Angle θ and constructed triangle AOB for expressing trigonometrical functions as ratios.

$$\textbf{\textit{Cotangent}} \text{ of the angle } \theta = \frac{OB}{BA} = \frac{\text{adjacent side}}{\text{opposite side}}$$

$$\textbf{\textit{Secant}} \text{ of the angle } \theta = \frac{OA}{AB} = \frac{\text{hypotenuse}}{\text{adjacent side}}$$

$$\textbf{\textit{Cosecant}} \text{ of the angle } \theta = \frac{OA}{AB} = \frac{\text{hypotenuse}}{\text{opposite side}}$$

For the sake of brevity the names of the functions are contracted, thus: for *sine θ*, write *sin θ*; for cosine θ, write *cos θ*, etc.

The cosine, cotangent (cot.) and cosecant (cosec) of an angle are respectively the sine, tangent and secant of the complement of that angle.

In the second instance the trigonometrical functions are

defined by *certain lines* whose lengths depend upon the arc which measures the angle. These are virtually ratios but by taking what corresponds to the hypotenuse OA, of the triangle AOB, in fig. 9,395 as a ***radius of unity length*** of a circle the denominators of the ratios become unity or 1, and disappear leaving only the numerators, that is. a line instead of a ratio or

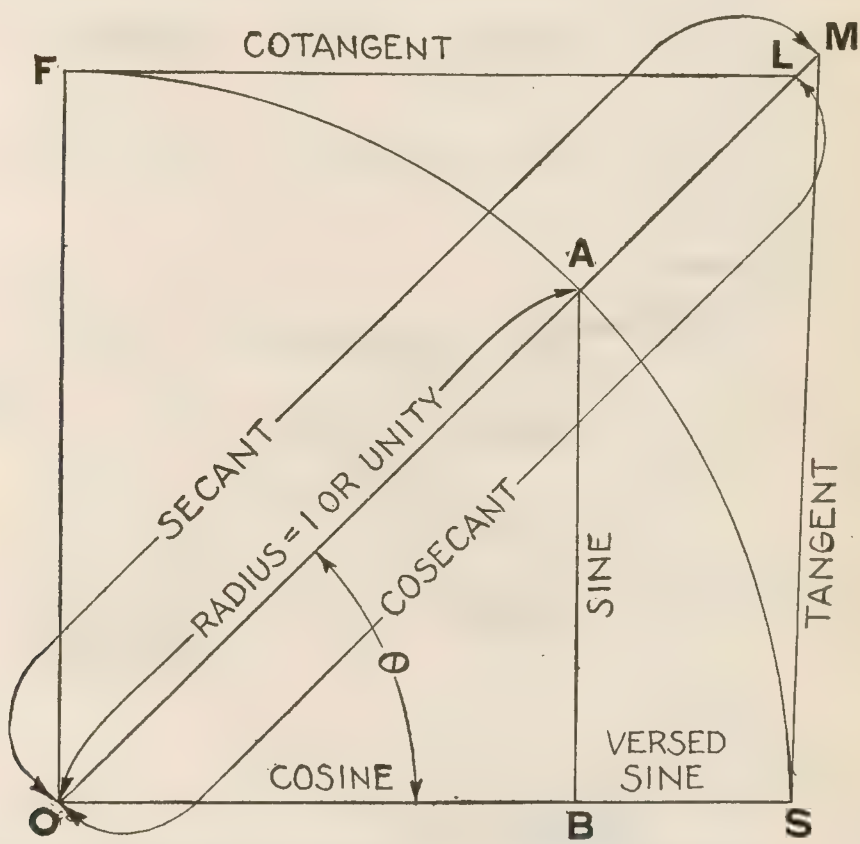


FIG. 9,396.—***Natural*** *trigonometrical functions*, or functions expressed as lines.

function; these lines are the so called ***"natural functions,"*** thus in fig. 9,396.

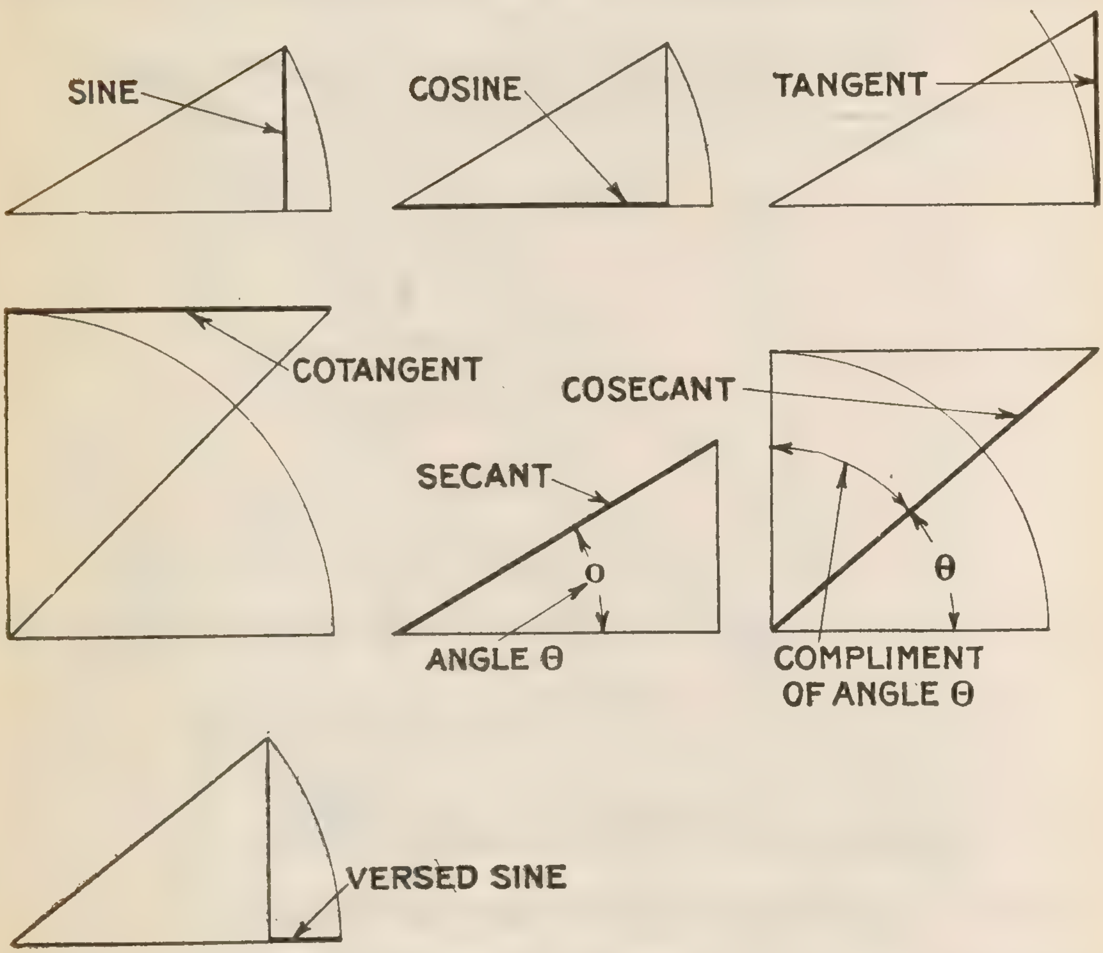
$$\textbf{\textit{Sine}}\text{ angle } \theta = \frac{AB}{\text{radius}} = \frac{AB}{1} = AB$$

$$\textbf{\textit{Cosine}}\text{ angle } \theta = \frac{OB}{\text{radius}} = OB$$

$$\textbf{\textit{Tangent}}\text{ angle }\theta = \frac{MS}{OS} = \frac{MS}{\text{radius}} = MS$$

$$\textbf{\textit{Cotangent}}\text{ angle }\theta = \text{tangent of complement of angle}$$

$$\theta = \frac{OM}{OF} = \frac{OM}{\text{radius}} = OM$$



Figs. 9,397 to 9,403.—The natural trigonometrical functions each shown separately for clearness. As elsewhere stated the cos., cot, and cosec. of an angle are respectively the sine, tan, and sec. of the complement of the angle.

$$\textbf{\textit{Secant}}\text{ angle }\theta = \frac{OM}{OS} = \frac{OM}{\text{radius}} = OM$$

$$\textbf{\textit{Cosecant}}\text{ angle }\theta = \text{secant of complement angle }\theta = \frac{OL}{OF} = \frac{OL}{\text{radius}} = OL$$

Versed sine angle $\theta = \frac{BS}{OS} = \frac{BS}{\text{radius}} = BS$

It is these natural trigonometrical functions that are especially useful, rather than the functions expressed as ratios, because, with the aid of the table given on the next page (repeated here from Guide No. 1, for convenience), the exact lengths of the functions for an arc of unity radius can be found.

Problem 1.—Find length of rafter for 12 ft. run and 8 ft. rise,

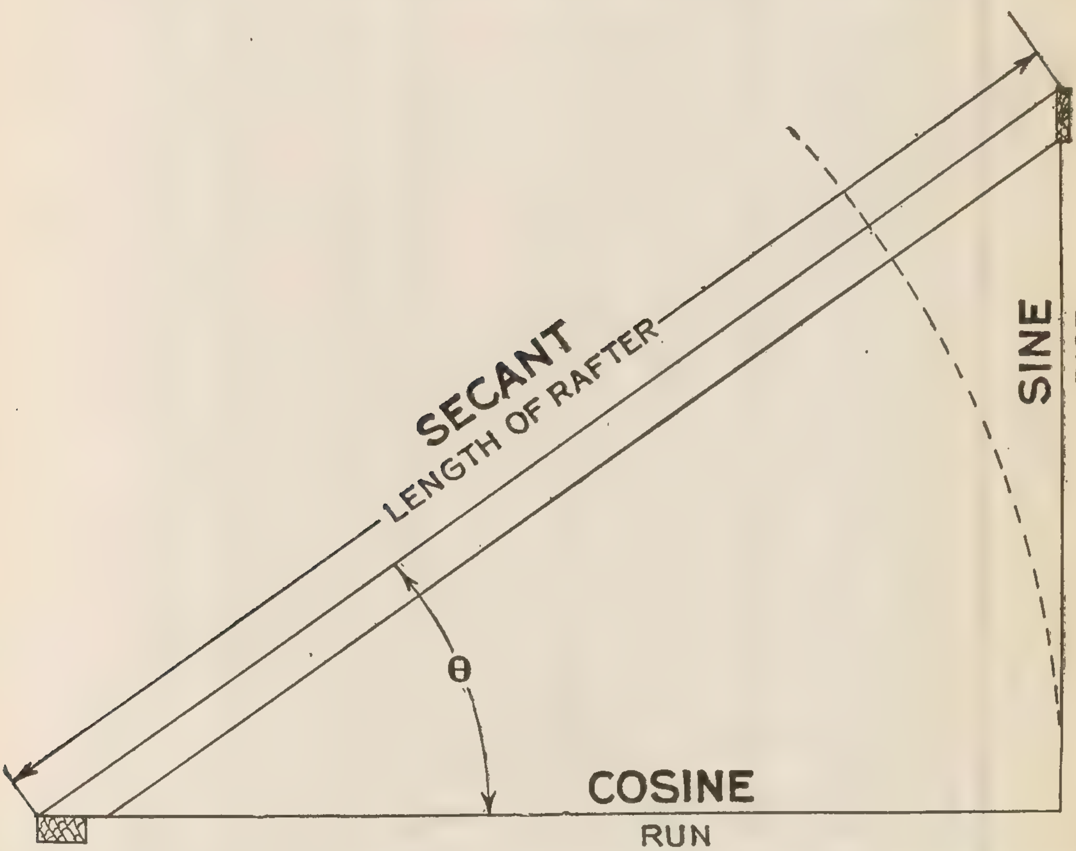


FIG. 9,404.—Common rafter in position between plate and ridge illustrating **cosine and tangent.**

allowing for 1½ in. ridge board.

In figs. 9,404 and 9,405

$$\tan\theta = \frac{\sin}{\cos} = \frac{\text{rise}}{\text{run}} = .67$$

From table on the next page, .67 in column of tangents correspond to angle of 34°.

As given in table below for tan θ = .67 the rafter makes an angle of 34° with the horizontal.

NATURAL TRIGONOMETRICAL FUNCTIONS

Degree	Sine	Cosine	Tangent	Secant	Degree	Sine	Cosine	Tangent	Secant
0	.00000	1.0000	.00000	1.0000	46	.7193	.6947	1.0355	1.4395
1	.01745	.9998	.01745	1.0001	47	.7314	.6820	1.0724	1.4663
2	.03490	.9994	.03492	1.0006	48	.7431	.6691	1.1106	1.4945
3	.05234	.9986	.05241	1.0014	49	.7547	.6561	1.1504	1.5242
4	.06976	.9976	.06993	1.0024	50	.7660	.6428	1.1918	1.5557
5	.08716	.9962	.08749	1.0038	51	.7771	.6293	1.2349	1.5890
6	.10453	.9945	.10510	1.0055	52	.7880	.6157	1.2799	1.6243
7	.12187	.9925	.12278	1.0075	53	.7986	.6018	1.3270	1.6616
8	.1392	.9903	.1405	1.0098	54	.8090	.5878	1.3764	1.7013
9	.1564	.9877	.1584	1.0125	55	.8192	.5736	1.4281	1.7434
10	.1736	.9848	.1763	1.0154	56	.8290	.5592	1.4826	1.7883
11	.1908	.9816	.1944	1.0187	57	.8387	.5446	1.5399	1.8361
12	.2079	.9781	.2126	1.0223	58	.8480	.5299	1.6003	1.8871
13	.2250	.9744	.2309	1.0263	59	.8572	.5150	1.6643	1.9416
14	.2419	.9703	.2493	1.0306	60	.8660	.5000	1.7321	2.0000
15	.2588	.9659	.2679	1.0353	61	.8746	.4848	1.8040	2.0627
16	.2756	.9613	.2867	1.0403	62	.8829	.4695	1.8807	2.1300
17	.2924	.9563	.3057	1.0457	63	.8910	.4540	1.9626	2.2027
18	.3090	.9511	.3249	1.0515	64	.8988	.4384	2.0503	2.2812
19	.3256	.9455	.3443	1.0576	65	.9063	.4226	2.1445	2.3662
20	.3420	.9397	.3640	1.0642	66	.9135	.4067	2.2460	2.4586
21	.3584	.9336	.3839	1.0711	67	.9205	.3907	2.3559	2.5593
22	.3746	.9272	.4040	1.0785	68	.9272	.3746	2.4751	2.6695
23	.3907	.9205	.4245	1.0864	69	.9336	.3584	2.6051	2.7904
24	.4067	.9135	.4452	1.0946	70	.9397	.3420	2.7475	2.9238
25	.4226	.9063	.4663	1.1034	71	.9455	.3256	2.9042	3.0715
26	.4384	.8988	.4877	1.1126	72	.9511	.3090	3.0777	3.2361
27	.4540	.8910	.5095	1.1223	73	.9563	.2924	3.2709	3.4203
28	.4695	.8829	.5317	1.1326	74	.9613	.2756	3.4874	3.6279
29	.4848	.8746	.5543	1.1433	75	.9659	.2588	3.7321	3.8637
30	.5000	.8660	.5774	1.1547	76	.9703	.2419	4.0108	4.1336
31	.5150	.8572	.6009	1.1666	77	.9744	.2250	4.3315	4.4454
32	.5299	.8480	.6249	1.1792	78	.9781	.2079	4.7046	4.8097
33	.5446	.8387	.6494	1.1924	79	.9816	.1908	5.1446	5.2408
34	.5592	.8290	.6745	1.2062	80	.9848	.1736	5.6713	5.7588
35	.5736	.8192	.7002	1.2208	81	.9877	.1564	6.3138	6.3924
36	.5878	.8090	.7265	1.2361	82	.9903	.1392	7.1154	7.1853
37	.6018	.7986	.7536	1.2521	83	.9925	.12187	8.1443	8.2055
38	.6157	.7880	.7813	1.2690	84	.9945	.10453	9.5144	9.5668
39	.6293	.7771	.8098	1.2867	85	.9962	.08716	11.4301	11.474
40	.6428	.7660	.8391	1.3054	86	.9976	.06976	14.3007	14.335
41	.6561	.7547	.8693	1.3250	87	.9986	.05234	19.0811	19.107
42	.6691	.7431	.9004	1.3456	88	.9994	.03490	28.6363	28.654
43	.6820	.7314	.9325	1.3673	89	.9998	.01745	57.2900	57.299
44	.6947	.7193	.9657	1.3902	90	1.0000	Inf.	Inf.	Inf.
45	.7071	.7071	1.0000	1.4142		—	—	—	—

NOTE.—***For intermediate values*** reduce angles from degrees, minutes and seconds to degrees and decimal parts of a degree (as 40° 21′ 30″ = 46.358°3) and employ interpolate or consult a larger table.

By comparing fig. 9,405, showing rafter with fig. 9,396, it will be seen that the rafter corresponds to the secant (both figures being lettered the same), hence look in a table of natural trigonometrical functions, giving values for secant, and find 1.2062 value of secant for 34°. Now since the run corresponds (in fig. 9,405) to the unity radius, multiply the value found by 12, thus

$$\text{artificial length of rafter} = 1.2062 \times 12 = 14.46 \text{ ft.}$$

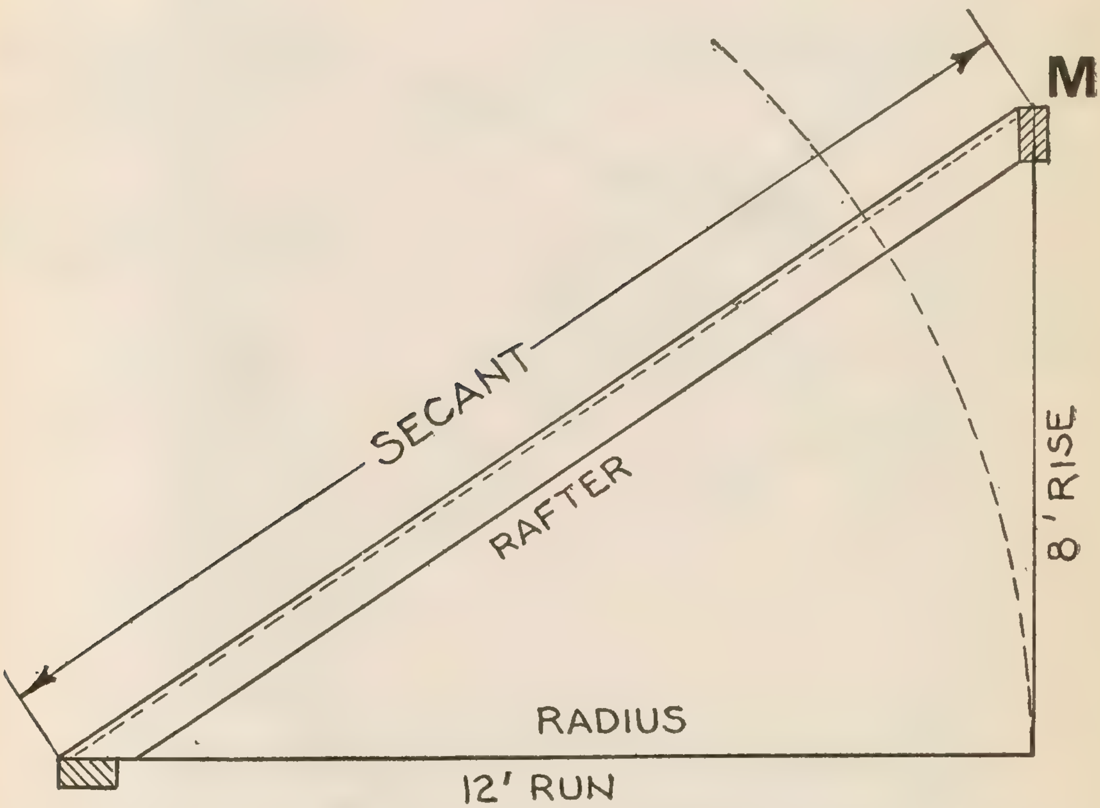


FIG. 9,405.—***Problem 1.*** Method of finding rafter length by aid of natural *secant*.

deducting ½ of ridge board width.

$$\text{length of rafter} = 14.46 - .75 = 13.71 \text{ ft.}$$

Problem 2.—What width board is required to cut 45° block forms for a circular deck 12 ft. in diameter allowing margin of 3 ins. for joints.

The width of board = "rise of arc" + margin for joint. In fig. 9,396

(compare with fig. 9,406) the rise of the arc is equal to the *versed sine* MS, of half the angle, or 22½°. Hence look in the table of natural trigonometrical functions and find *versed sine* = .0696 for 22½°; this is the rise of the arc if radius of the porch were 1 ft. Hence for 6 ft. radius (porch 12 ft .in diameter)

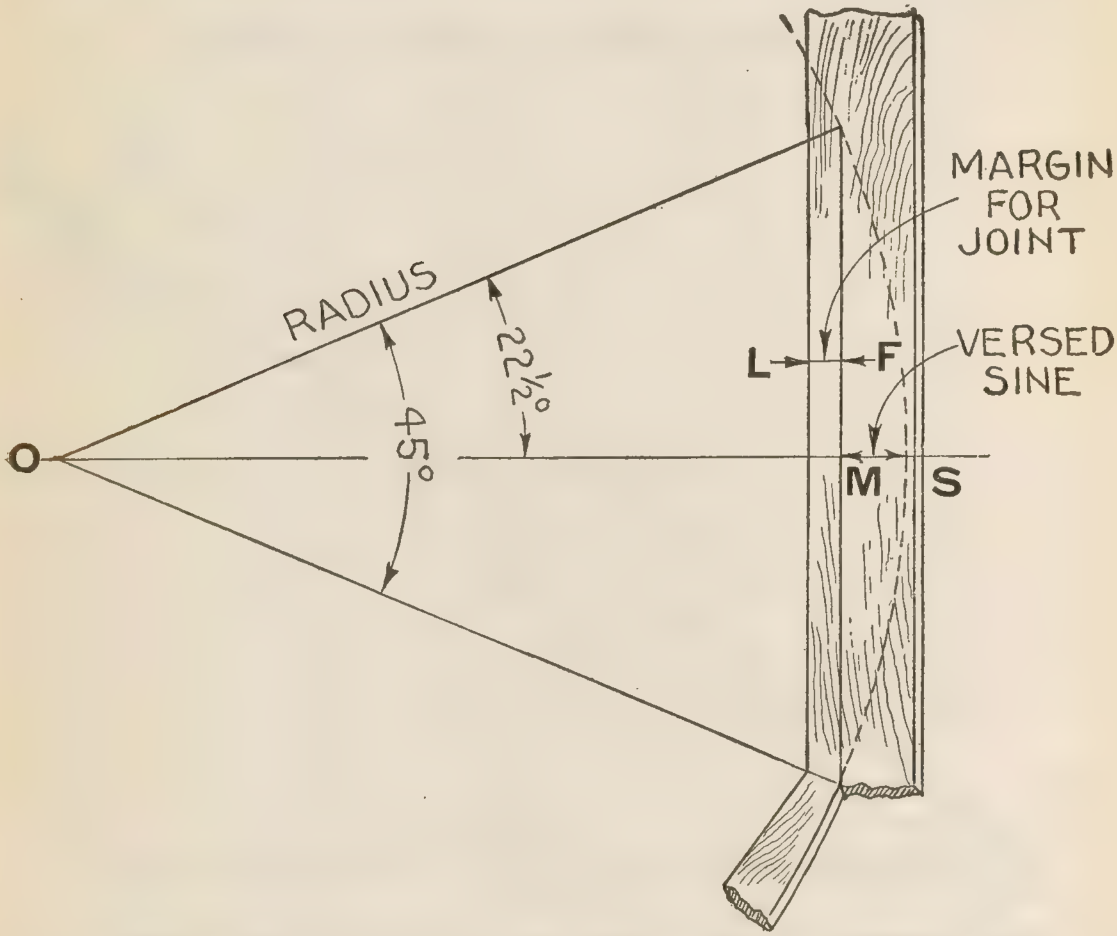


Fig. 9,406.—***Problem 2.*** Method of finding width of board for cutting circular deck or porch block forms by aid of the *versed sine*.

$$\text{rise of arc} = .0696 \times 6 = .4176 \text{ ft. or 5 ins. (approx.)}$$

$$\text{width of plank} = 5 \text{ ins. rise} + 3 \text{ ins. (for joint)} = 8 \text{ ins.}$$

Problem 3.—If the common rafter on a building as found in problem 1 be 14.46 ft. artificial length, what is the artificial length of a 45° hip.

Comparing fig. 9,407 with 9,396, clearly the length of the hip rafter corresponds to the secant of the angle the hip makes with the common rafter. Hence find in table, secant 45° = 1.4142. Multiply by length of common rafter (radius)

$$\text{artificial length of hip} \times 1.4142 = 14.46 = 20.45 \text{ ft. or } 20' \, 5\tfrac{3}{8}''$$

Problem 4.—In the roof construction shown in fig. 9,407 what

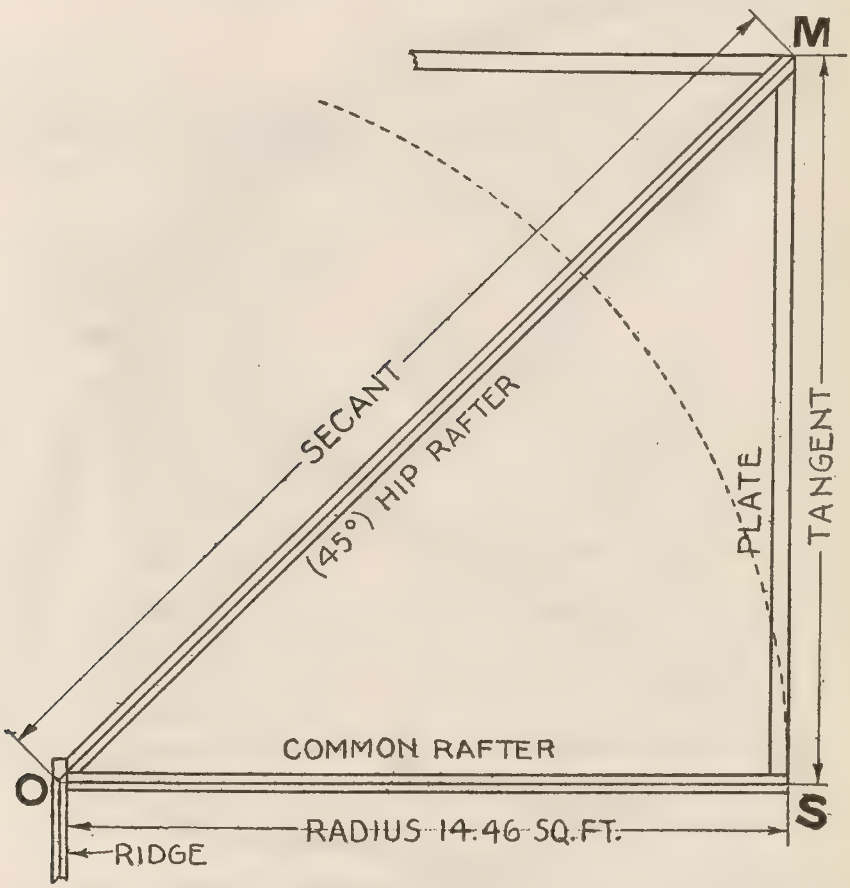


FIG. 9,407.—***Problems 3 and 4.*** Method of finding length of hip rafter and portion of plate intercepted between common and hip rafters by aid of the *secant* and tangent respectively.

is the length of the plate intercepted between the common and hip rafters?

Comparing the figure with fig. 9,396 it will be seen that the intercepted plate MS, corresponds to the tangent of the angle between the common and hip rafters.

Hence from table tangent 45° = 1, and from which

length MS, of intercepted plate = 1 × 14.46 = 14.46 ft. or 14′ 5½″

Problem 5.—A fancy grill work consisting of radial and vertical pieces is to be constructed in a semi-circular opening

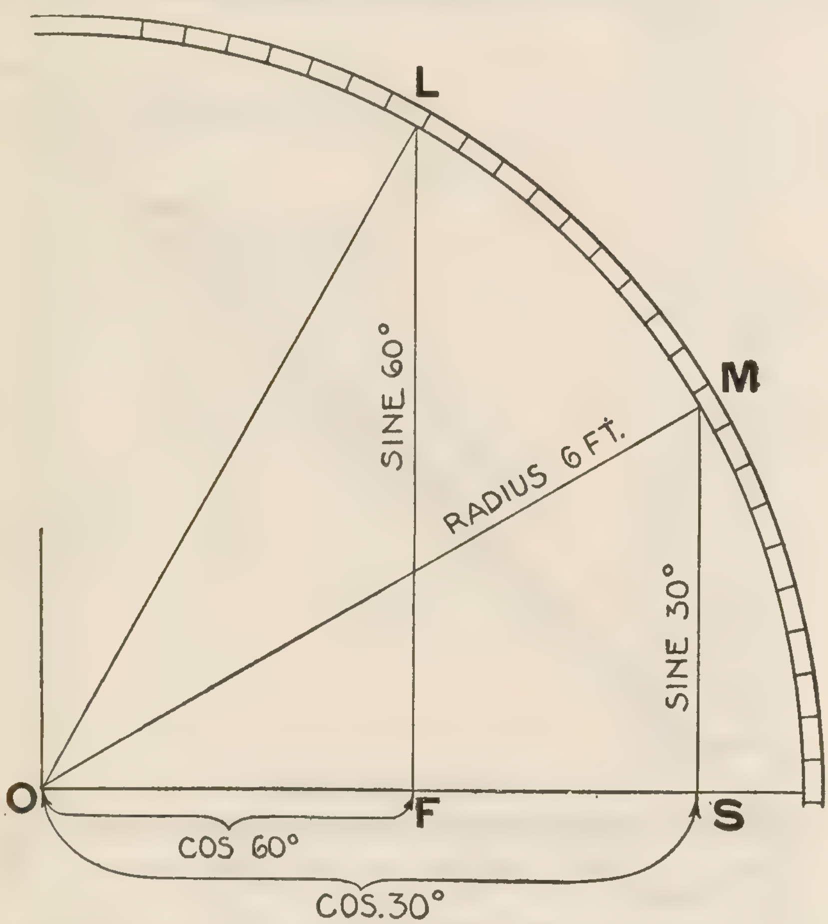


FIG. 9,408.—***Problems 5 and 6.*** Method of finding in a grill work construction length of vertical pieces and their distance front center by aid of sine and cosine respectively of the angle made by intersecting radial pieces with the horizontal.

having a 6 ft. radius as in fig. 9,408. Find the lengths of the vertical pieces as MS and LF, touching the circumference at 30° and 60° from the horizontal.

Comparing fig. 9,408 with 9,396 it will be seen that the vertical pieces MS

and LF, correspond to sine of the angle made by the intersecting radial piece with the horizontal. Accordingly, from table

$$\text{sine}\begin{cases}30^\circ = .5\\60^\circ = .866\end{cases}$$

hence length of vertical pieces

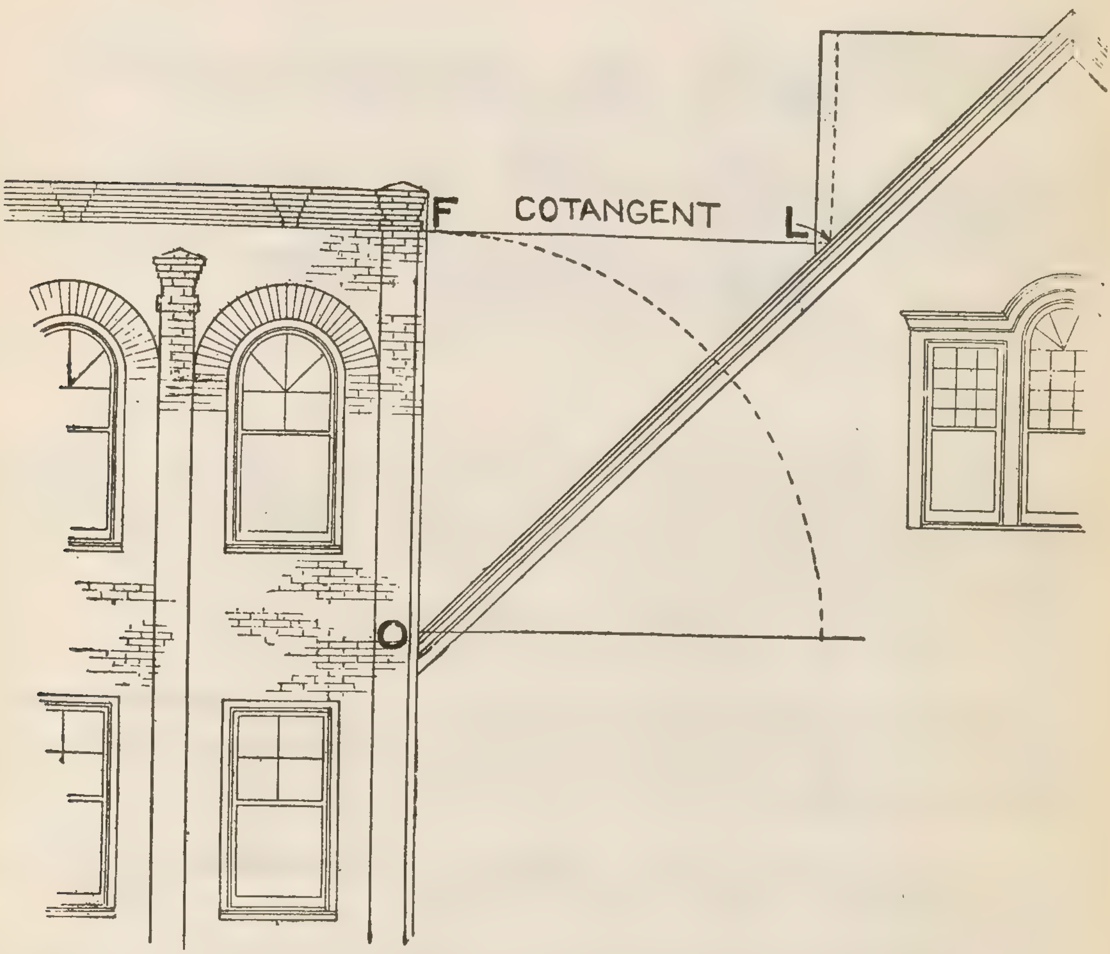


FIG. 9,409.—***Problems 7 and 8.*** Method of finding length of bridge from side of building to given point on adjacent pitch roof by aid of cotangent, and of finding slant length of roof by aid of cosecant.

$$\begin{aligned}\text{Ms} &= .5 \times 6 = 3\text{ ft.}\\ \text{LF} &= .866 \times 6 = 5.2\text{ ft. or } 5'\,2\tfrac{3}{8}''\end{aligned}$$

Problem 6.—In laying out the grill work fig. 9,408, how far must the foot of the pieces LF and MS, be spaced from the center O, to bring them into a vertical position?

The distances OF and OS, correspond to the cosine of angles 30° and 60° respectively. Accordingly from table

$$\text{Cosine}\begin{cases} 30° = .866 \\ 60° = .5 \end{cases}$$

hence distances

$$OS = .866 \times 6 = 5.2 \text{ ft.} = 5' \, 3\tfrac{1}{2}''$$
$$OF = .5 \times 6 = 3 \text{ ft.}$$

Problem 7.—A bridge is to be constructed from the top of a building to an opening in the roof of an adjacent building as in fig. 9,409. If the rise OF; to the point of entry L, be 15 ft. and the pitch of the roof be 1/3, what length beams FL, are required?

Comparing the figure with fig. 9,396, it is seen that the bridge FL, corresponds to the cotangent. Now ⅓ pitch corresponds to an angle of 34°, and from table (page **2,826**), cotangent of 34° = 1.483. Hence, length of beams required, or

$$FL = 1.483 \times 15 = 22.25 \text{ ft. } 22' \, 3''$$

Problem 8.—In estimating amount of roofing material necessary to cover side of roof from O to L, in fig. 9,409 what is the distance from O to L?

Comparing with fig. 9,396, it is seen that OL, corresponds to the cosecant. Accordingly from table, cosec 34° = 1.788.

Hence length slant surface or

$$OL = 1.788 \times 15 = 26.82 \text{ or } 26' \, 9\tfrac{7}{8}''$$

CHAPTER 147

Principles of Pattern Cutting or Development of Surfaces

By definition, a development is *a full view drawing of an object in which all the surfaces of the object are shown in the plane of the drawing board:* that is, the development is a drawing which represents the surfaces of the object unfolded or unrolled or spread out in the plane of the drawing board so that the entire surface is seen in one plane true size without any foreshortening.

In sheet metal work solids are divided into two general classes, according as the surfaces of the solid are

1. Elementary, or
2. Warped.

Solids having elementary surfaces may be developed accurately, and those having warped surfaces, only approximately. Objects having elementary surfaces may be formed by simply folding or rolling the metal pattern, whereas if the object have warped surfaces, the metal pattern must undergo the operation of *raising* or *bumping* to bring the pattern to the true shape of the object when folded or rolled.

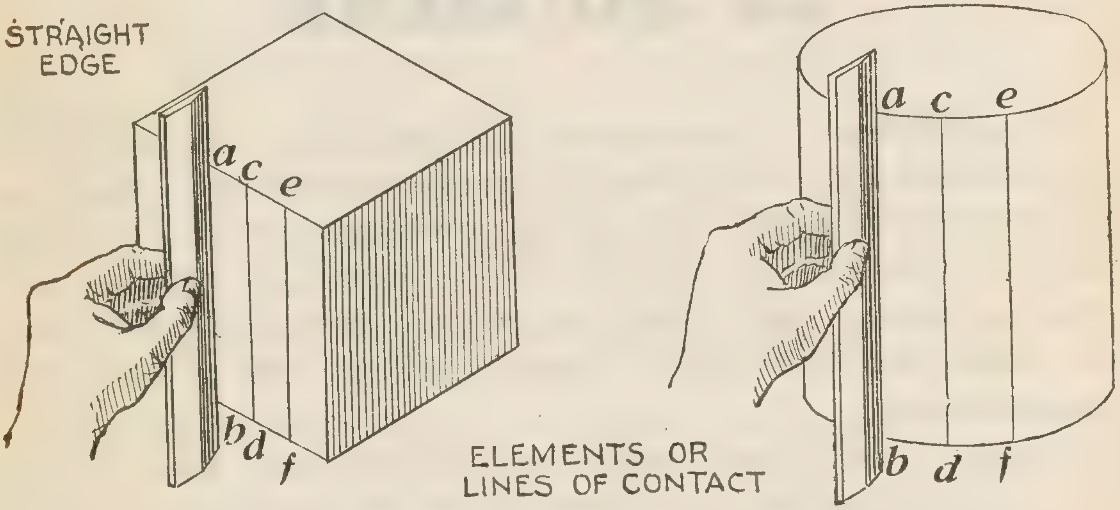
By definition an elementary surface is one in which *a straight*

edge may be placed in continuous contact in one direction, as in figs. 9,410 and 9,411.

The line of contact is an element of the surface. Elementary surfaces may be either

1. Plane, or
2. Curved

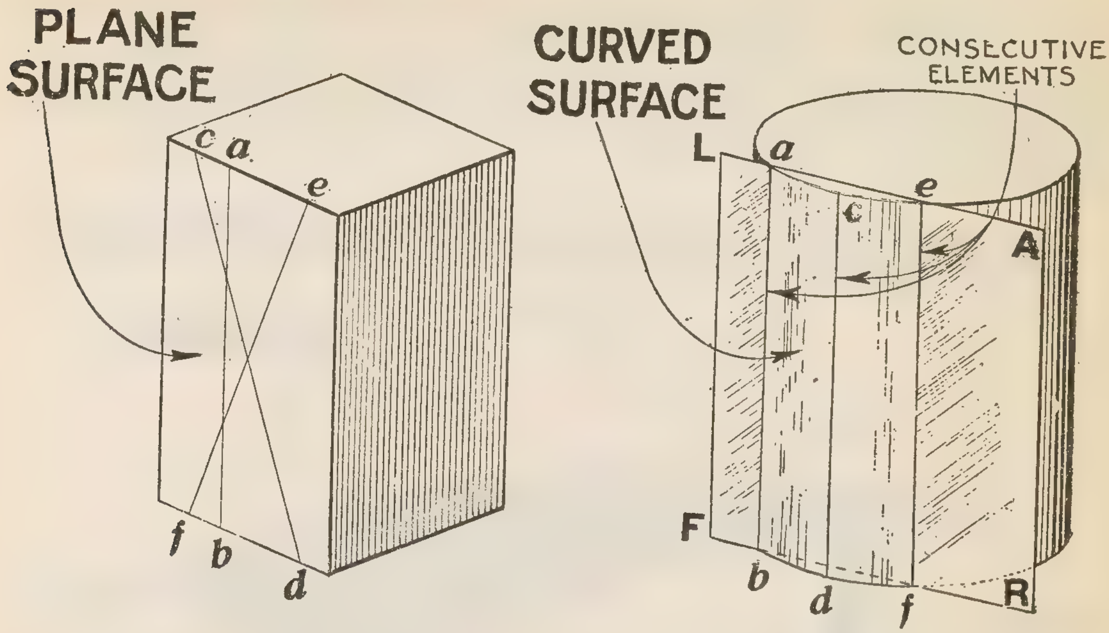
as shown in figs. 9,412 and 9,413. By definition a plane surface is *one in which elements may be drawn in any direction*, as *ab*, *cd*, *ef* in fig. 9,412. A curved surface is *one in which no three consecutive* elements lie in the same plane*, as in fig. 9,413.



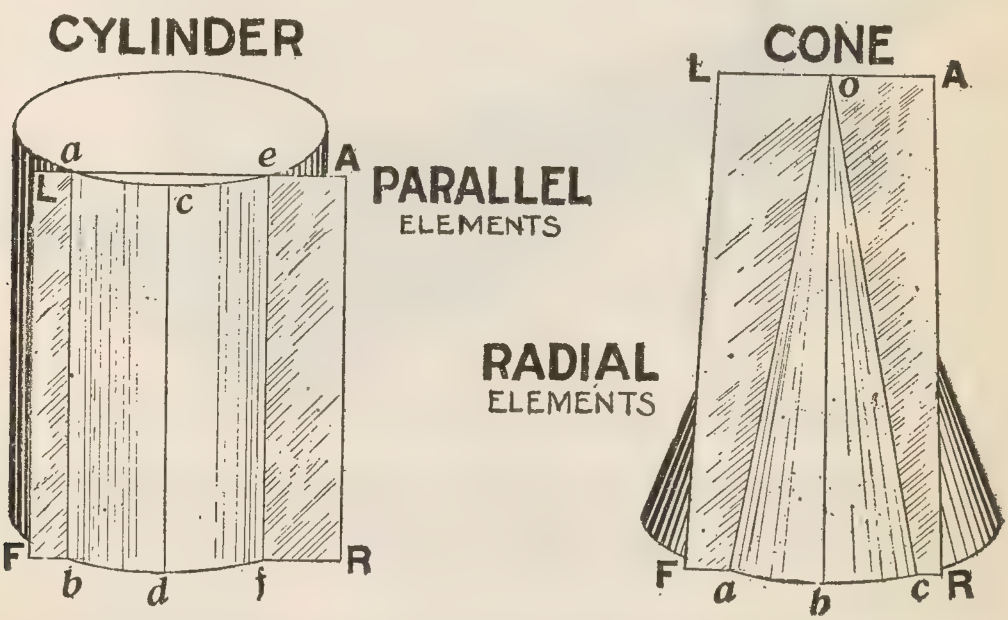
FIGS. 9,410 and 9,411.—Elementary surfaces or surfaces in which a straight edge may be placed in *continuous contact* with the surface, as for instance in positions *ab*, *cd*, *ef*, etc. The imaginary line of contact of the straight edge with the surface is called an *element* of the surface.

In the figure let *ab*, *cd* and *ef* be three consecutive elements, then if a plane LARF pass through *ab* and *ef*, the intervening element *cd* will not lie in this plane. The curved surface shown in fig. 9,413 is a *cylindrical* surface or curved surface having parallel elements, as distinguished from another class of curved surfaces which does not have parellel elements, as for instance a conical surface. The distinction is shown in figs. 9,414 and 9,415.

*NOTE—***Consecutive elements*** are those which lie infinitely close to each other. Thus in fig. 9,410 the elements *ab*, *cd* and *ef* are so close to each other that no other elements could be drawn or imagined to lie between them. It should be noted, however, that in fig. 9,413, these elements are drawn quite far apart to clearly illustrate the principle which defines a curved surface



FIGS. 9,412 and 9,413.—Plane and curved surfaces. Elements of a plane surface may be drawn in the surface in any direction as *ab*, *cd*, *ef*, as in fig. 9,412. In a curved surface no three *consecutive* elements lie in the same plane as in fig. 9,413.



FIGS. 9,414 and 9,415.—Distinction between ***cylindrical*** and ***conical*** surfaces. Fig. 9,414, elements parallel; fig. 9,415, elements radial. Both surfaces being curved surfaces, no three consecutive elements lie in the same plane as indicated by plane LARF, passing through the first and third of the three consecutive elements *ab*, *cd*, and *ef*.

By definition, surfaces of the second general class known as *warped surfaces* are those in which *a straight edge may be placed in contact only at a point*, as for instance, the sphere shown in fig. 9,416.

Patterns for such surface can be cut only to the approximate shape, as for instance in fig. 9,417 the pattern *abdfec*, for a section of the surface of a

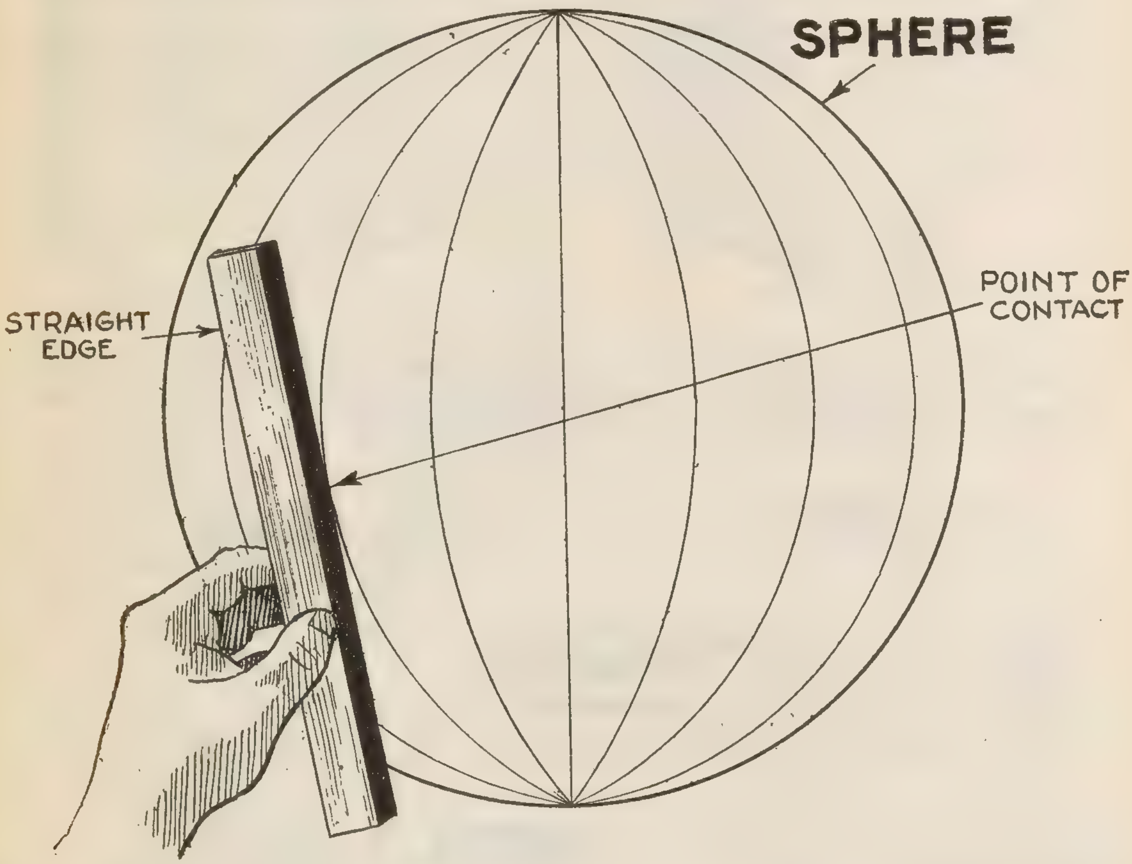


FIG. 9,416.—***Warped surface*** or *surface in which a straight edge can be placed in contact only at a point.*

sphere. This pattern, as can be seen, must be warped or hammered to the shape *abd'fec'*, so that its surface will coincide with the surface of the sphere. The figure clearly shows the shape of the pattern before and after warping.

From the explanations thus far given it must be evident that patterns may be cut accurately for objects having

elementary surfaces and only approximately for objects having warped surfaces.

Considering these two classes of surfaces, various methods are employed in developing the surfaces in laying out patterns as

1. Methods applied to objects having elementary surfaces.

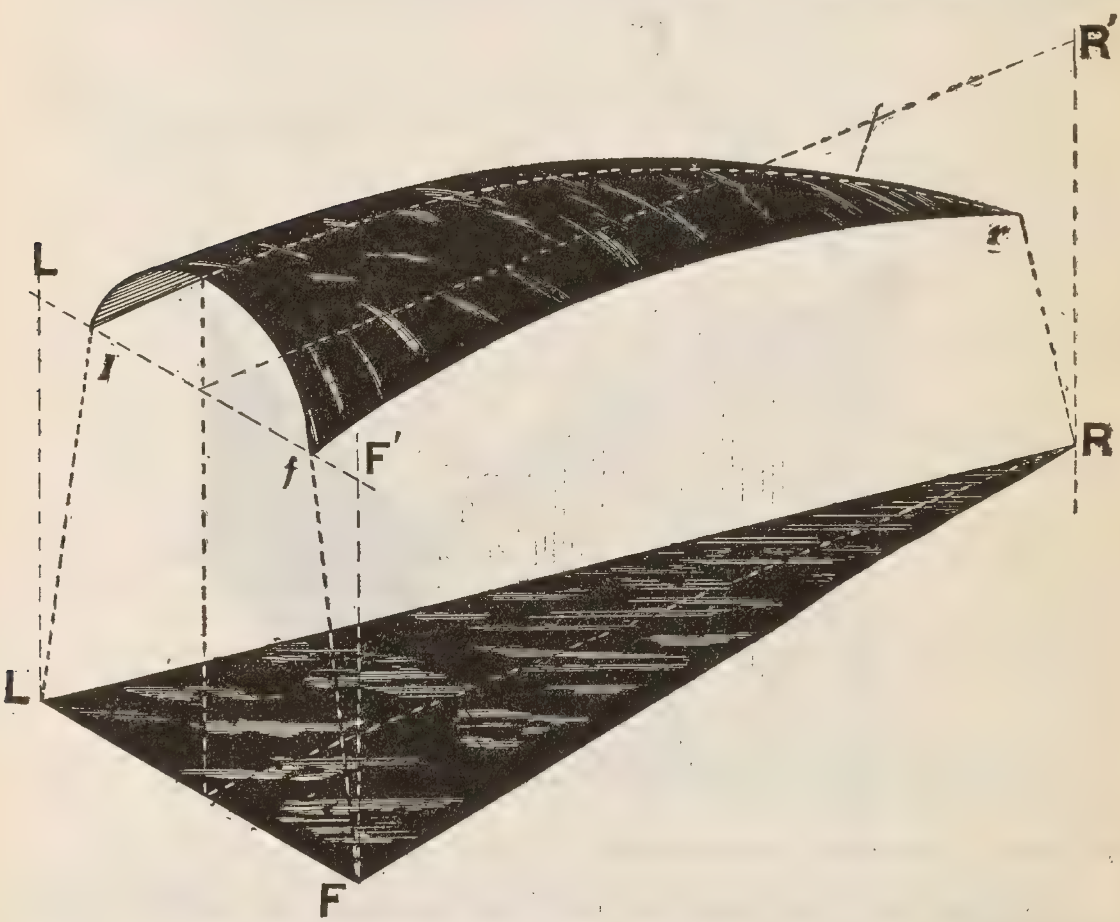


Fig. 9,417.—Approximate pattern as cut for a section of a warped surface showing shape of pattern before and after warping

a. Parallel line
b. Radial line
c. Triangulation

2. Methods applied to objects having warped surfaces.

1. Elementary Surfaces

Development of Patterns by Parallel Lines.—In any development a plan and elevation of the object is first drawn, and from these views the development or shape of the pattern is obtained by laying off what is called a "*stretch out*" which is simply the outline of the object unfolded and laid out flat.

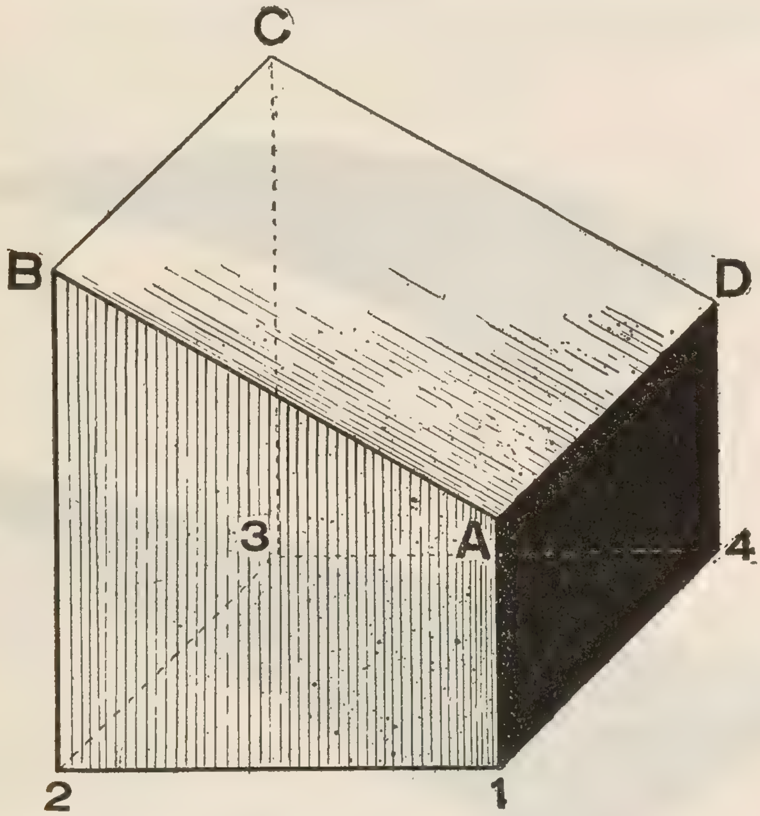


FIG. 9,418.—Prismoid in cabinet projection.

To illustrate the method of development by parallel lines, usually a cube is selected, as it is the simplest form. However, as all the surfaces of such a solid are alike, there is no variation in the pattern to distinguish the individual sides. Accordingly a prismoid, as shown in fig. 9,418, is here selected for the first example. Note carefully the general shape of the solid, especially the shape of the sides.

To develop, draw in fig. 9,420 a base line at the elevation of the base and on this base line lay off points 1, 2, 3, 4 and 1. The distances between these points are obtained from the plan. The distance between points 1 and 2, in stretchout equal distance between points 1 and 2, in plan; between 2 and 3, in stretchout equal distance between 2 and 3, in plan, and so on all the way around to the starting point 1. Erect perpendiculars at the points thus obtained and project over points A,D,B and C, from the elevation by the dotted lines parallel to the base line. The intersections of these dotted lines with the perpendiculars give the heights of the perpendiculars corresponding to the heights of the edges of the prismoid,

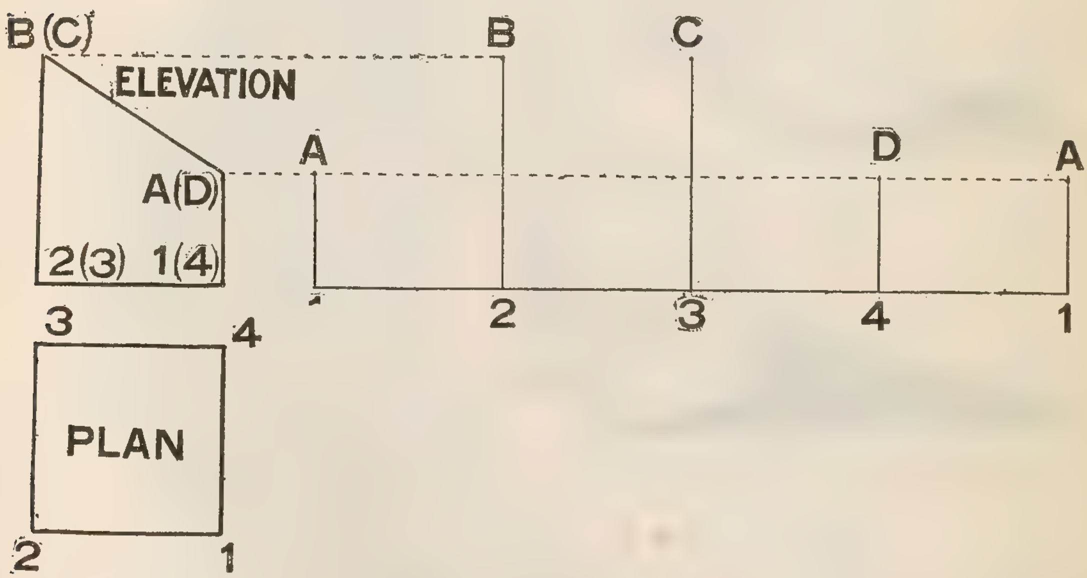


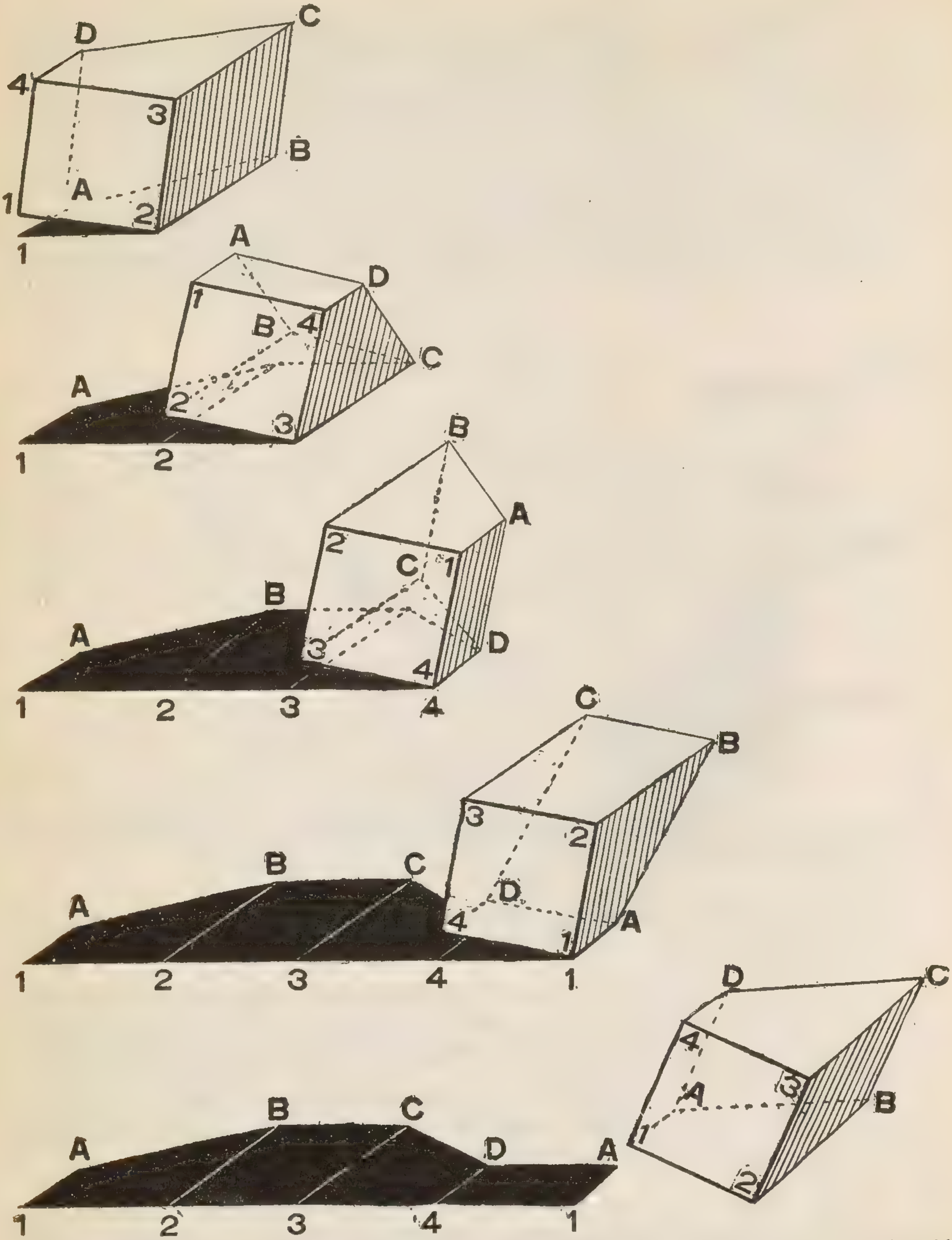
FIG. 9,419 to 9,421.—Development of pattern *by parallel lines* for the prismoid shown in fig. 9,418; base line and perpendiculars

that is, A1, in stretchout equal A1, in elevation; B2, in stretchout equal B2, in elevation, etc.

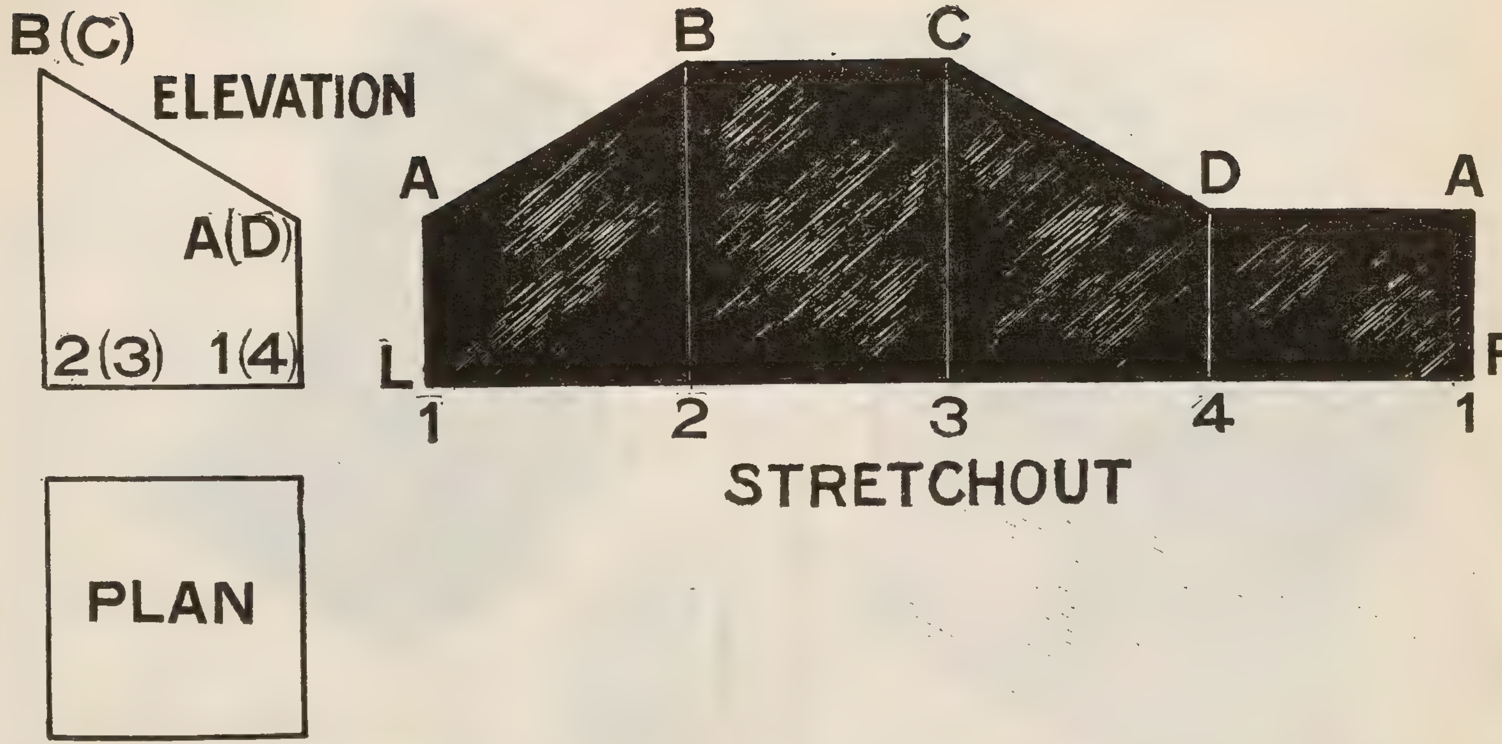
The stretchout is now completed by joining the points A,B,C,D and A. The completed stretchout is shown in fig. 9,428. The moving picture (figs. 9,422 to 9,426) shows the progressive development of the pattern.

Example.—Develop a pattern for the sides of the oblique parallelopipedon shown in fig. 9,430. ***Case 1.*** Development on line A1; ***Case 2.*** Development referred to base line.

Case 1.—First draw an elevation and plan of the parallelopipedon in orthographic projection as shown in figs. 9,431 and 9,433, lettering these views to correspond with the numbers and letters of fig. 9,418.



FIGS. 9,422 to 9,426.—Moving picture of development of pattern by parallel lines for the prismoid of fig. 9,418, showing prismoid rolling over on its sides and pattern progressively developed.



FIGS. 9,427 to 9,429—Development of pattern ***by parallel lines*** for the prismoid shown in fig. 9,418; stretch out or pattern completed.

Draw A1, equal to and parallel to A1, in elevation. Draw 12, equal to 12, in elevation making angle A12, equal 60°.

Through points 2 and A, draw lines respectively parallel to A1, and 12, obtaining point B, and completing the first section of the pattern.

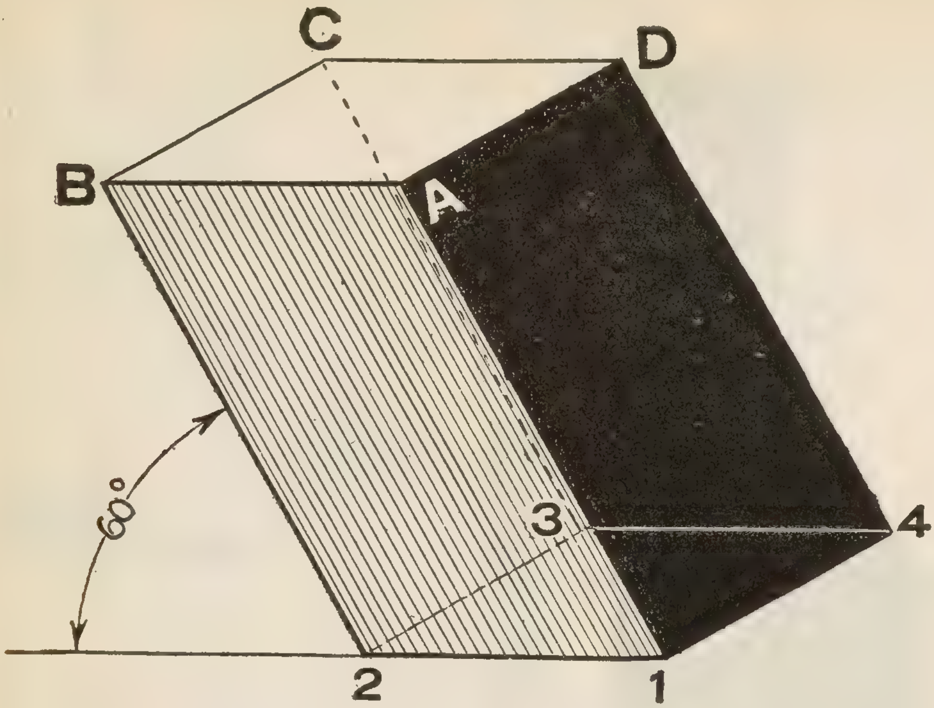
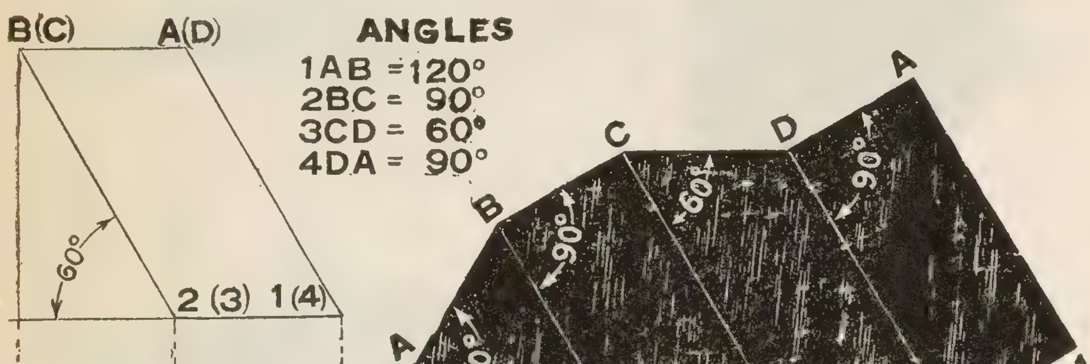
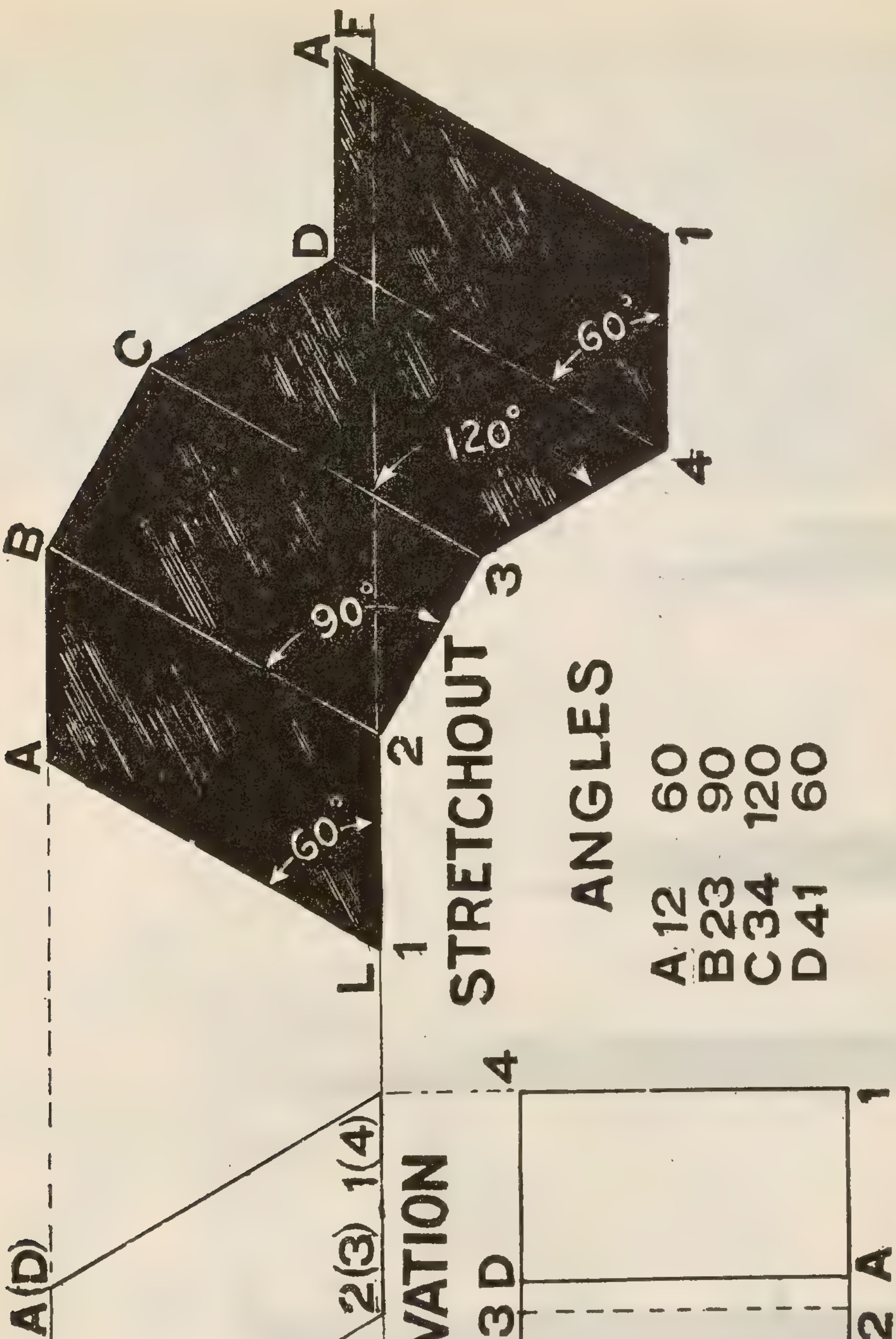


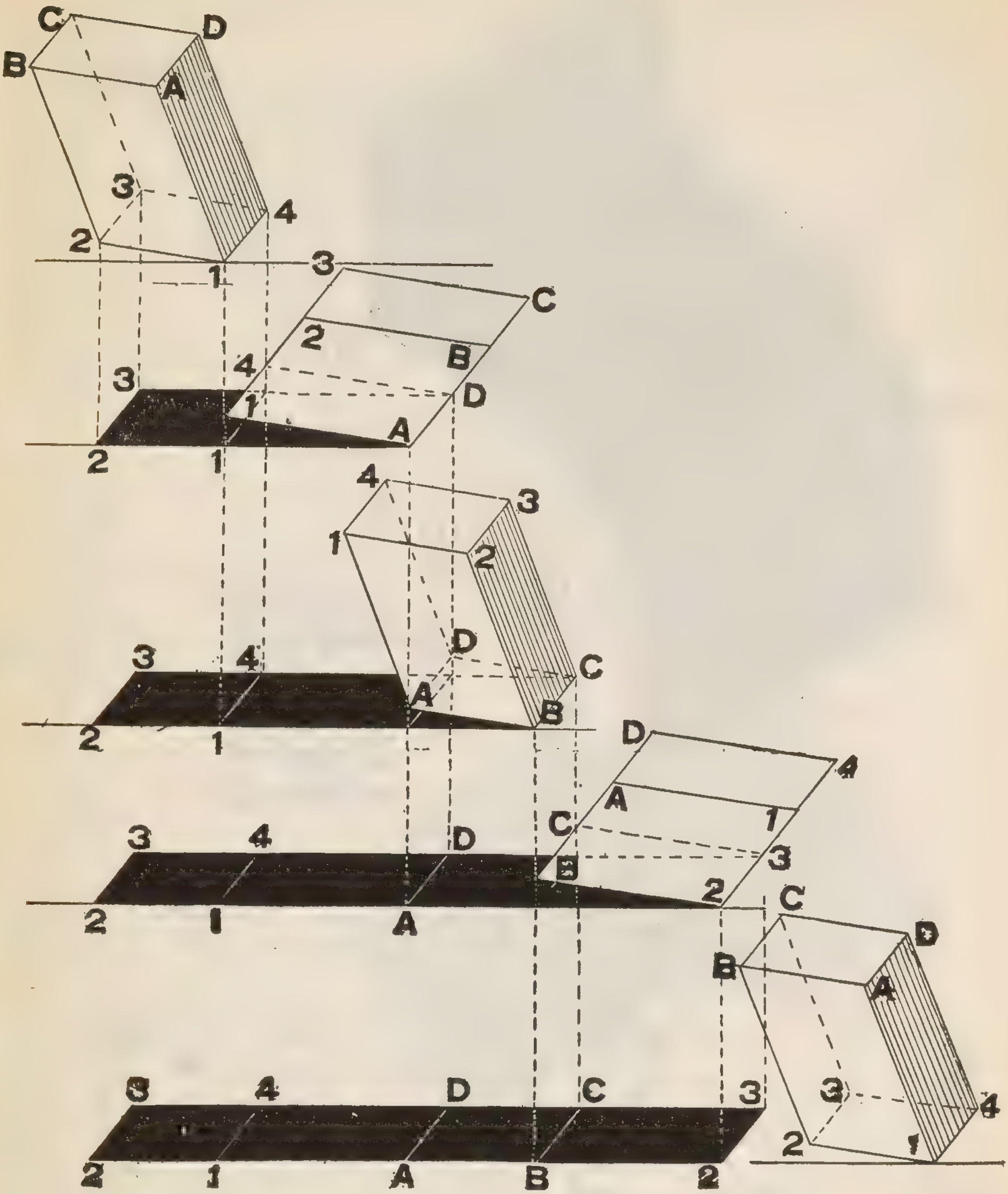
FIG. 9,430.—Oblique parallelopipedon in cabinet projection.



FIGS. 9,931 to 9,933.—Development of pattern ***by parallel lines*** for the oblique parallelopipedon shown in fig. 9,430 ***case 1***. Development on line A1.



FIGS. 9,434 to 9,436.—Development of pattern *by parallel lines* for the oblique parallelopipedon shown in fig. 9,430. *Case 2.* Development referred to base line.



FIGS. 9,437 to 9,441.—Moving picture of development of pattern by parallel lines for the oblique parallelopipedon of fig. 9,430, showing the parallelopipedon rolling over on its sides and pattern progressively developed.

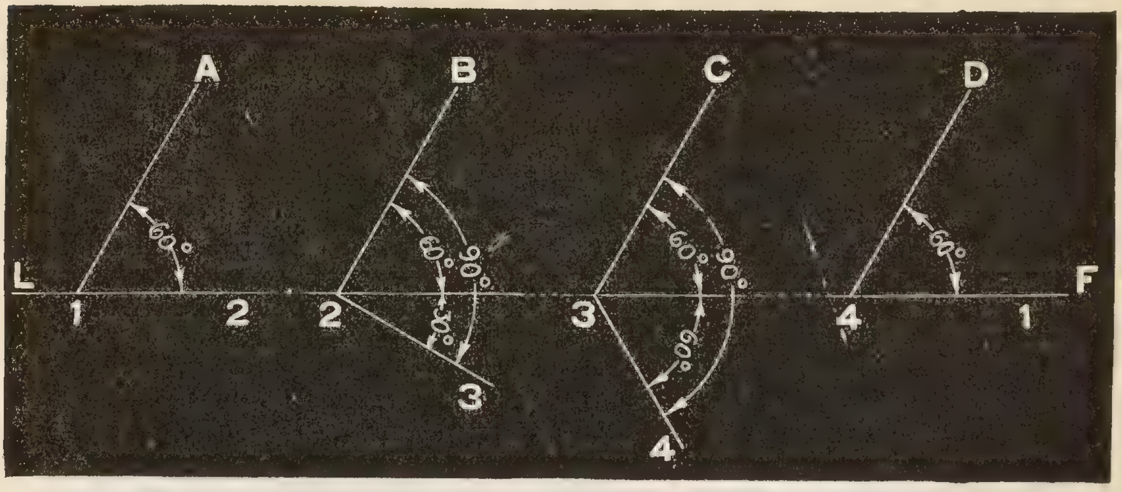


FIG. 9,442 to 9,445.—Angles of the oblique parallelopipedon shown in fig. 9,430 and the required laying off angles referred to laying off line LF. The reason for obtaining values referred to LF, is so that the angles may be laid off by use of T square and 30-60° triangle as shown in fig. 9,446.

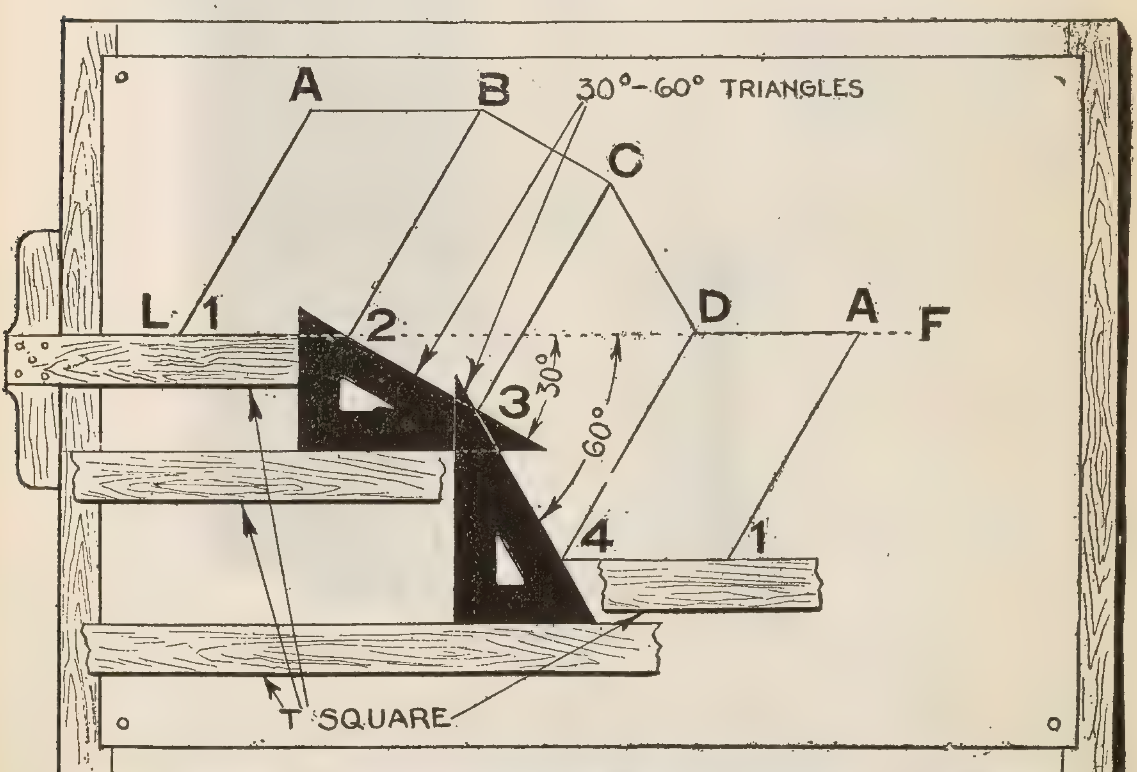


FIG. 9,446.—Method of laying out angles in the developments by the use of T square and 30°-60° triangle.

Similarly draw in lines 3C, 4D and 1A. Through points 3,4 and 1, draw lines parallel to 1A. Through B, draw line parallel to 23, obtaining point C; through C, draw line parallel to 34, obtaining line CD; and through D, line parallel to 41, obtaining line DA, thus completing the stretchout.

Case 2.—Draw in elevation and plan as in Case 1, and continue base 21 of elevation, giving a base line of reference LF, to which the angles are referred, as shown in figs. 9,434 to 9,436.

On LF, lay off points 1 and 2, spaced as in the elevation. Through 1 draw a line at an angle of 60° with LF, and project over point A in elevation, giving length 1A, on stretchout equal to length 1A in elevation. Through points 2 and A draw lines parallel to 1A and 12, respectively, completing the first section of the pattern 1AB2, in stretchout which is the development of one side of the solid.

Construct in a similar manner the remaining sections thus completing the stretchout 1ABCDA14321.

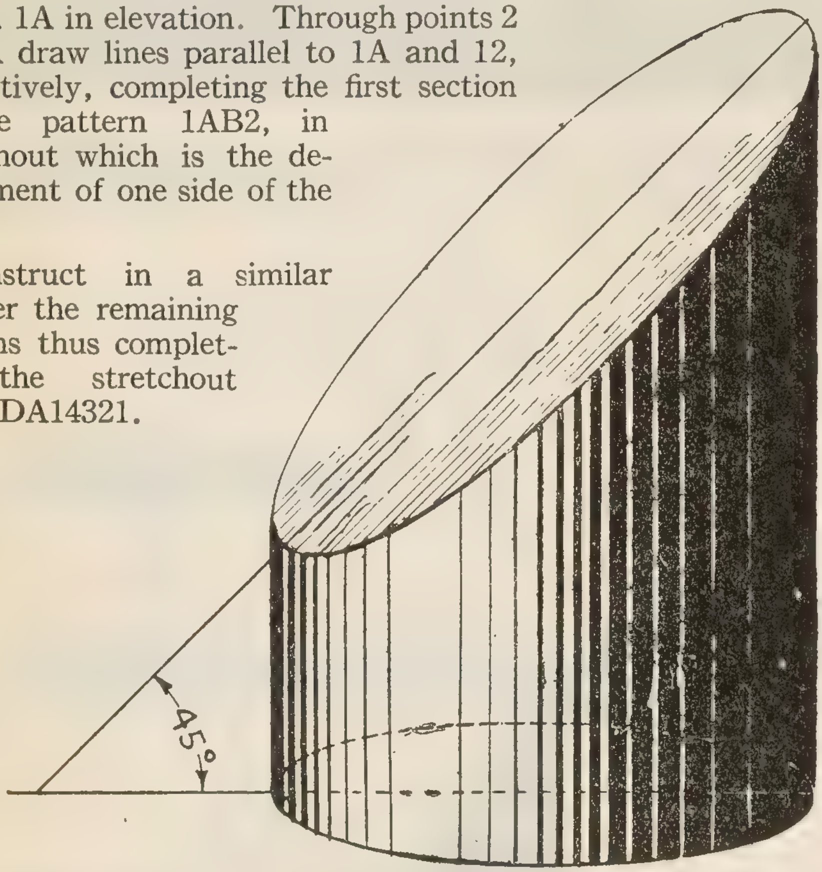
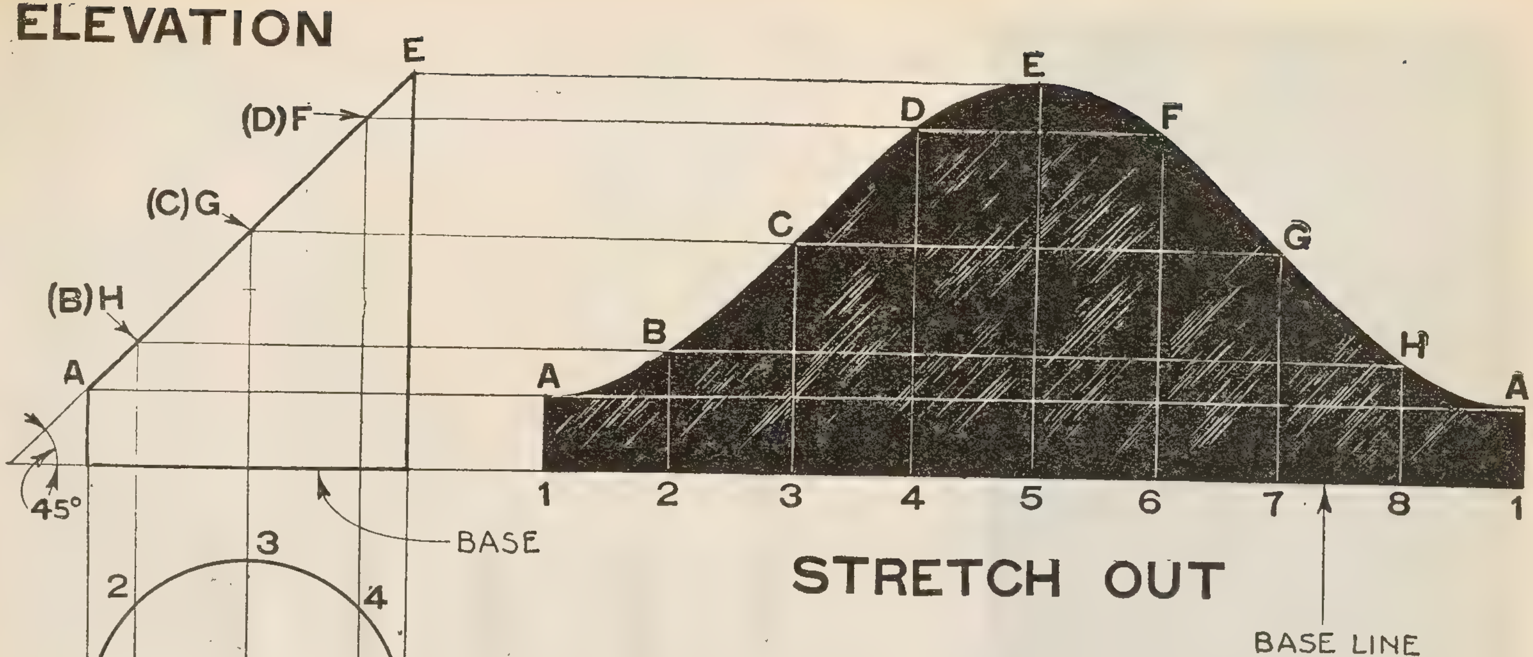


Fig. 9,447 —Cabinet projection of cylinder of revolution cut by plane inclined 45° to the base.

Figs. 9,442 to 9,445 show the various angles and the required angles referred to the "laying off line" LF, and fig. 9,446 the method of laying off these angles by use of T square and 30-60° triangle.

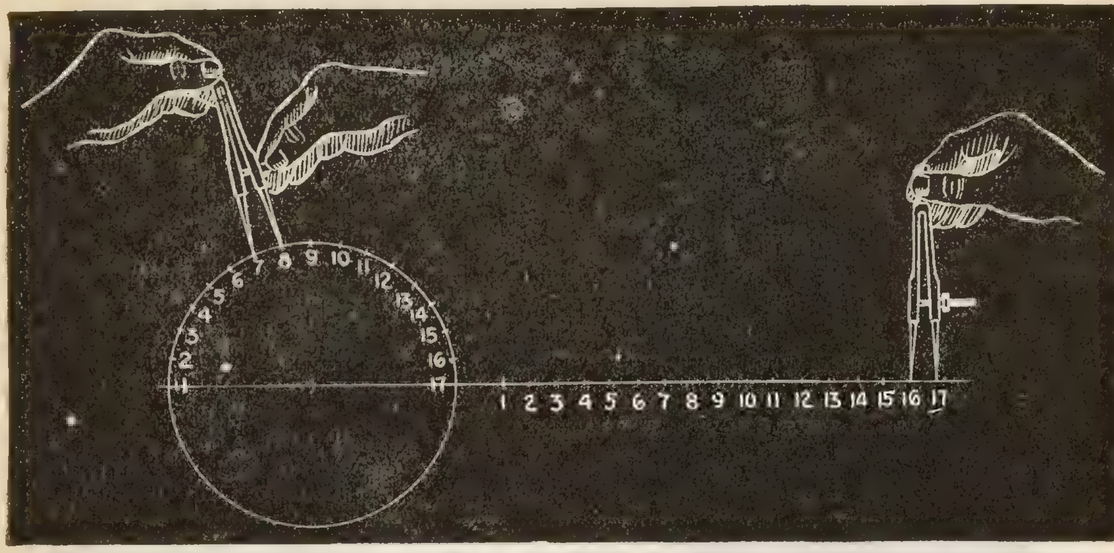



FIGS 9,448 to 9,450.—Development of pattern by *parallel lines* for the cylinder cut by 45° plane as shown in fig. 9,447.

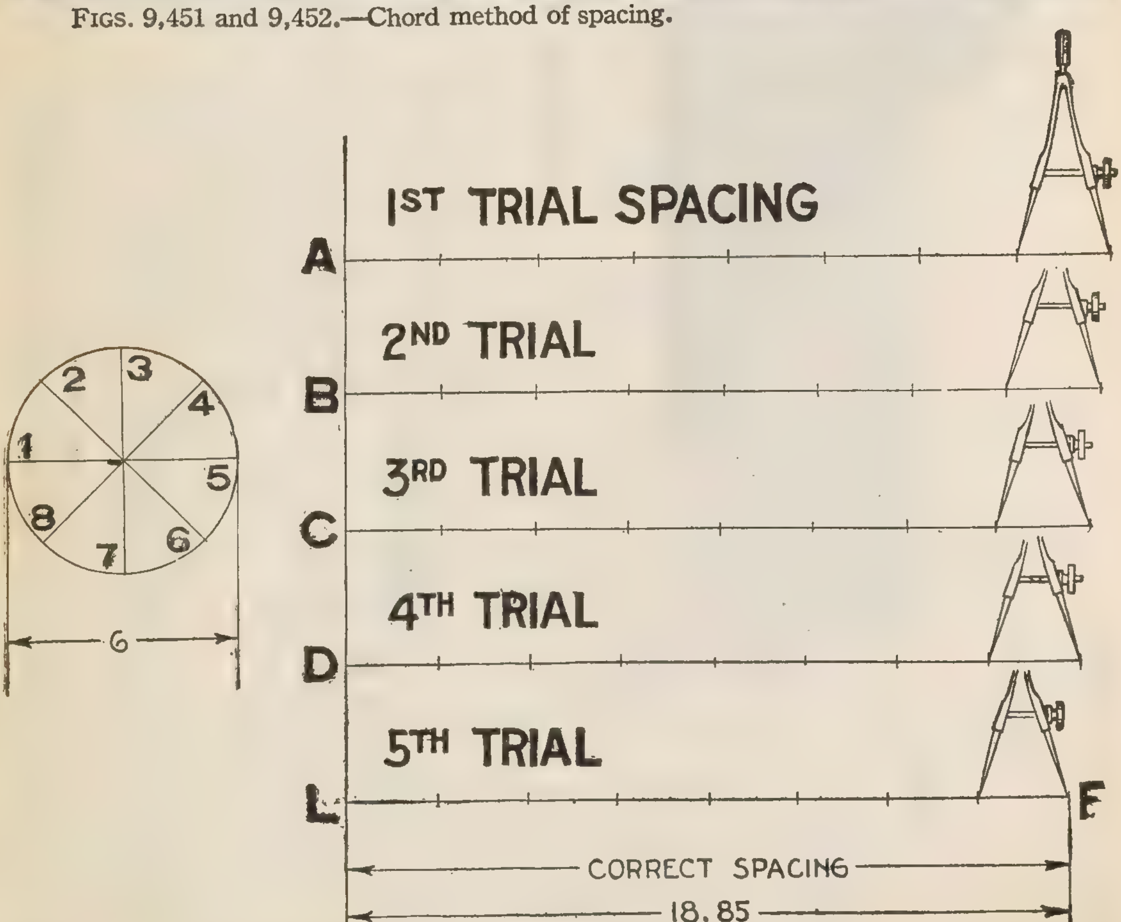
Example.—Develop a pattern for cylindrical surface of the cut cylinder shown in fig. 9,447.

In fig. 9,448, take any number of points on the circle as 1,2,3, 4,5,6,7 and 8, and project up in elevation obtaining points A(I), B (H), C(G), D(F) and E. Here some of the points coincide, that is some lie directly back of the others. Thus point 2, or its projection (B), lies back of 8, or its projection H, the parentheses indicating the fact.

Draw base line for the stretchout and lay off on this line points 1,2,3,4,5,6,7,8,1, spaced equal to the lengths of the arcs between points 1,2;2,3, etc., in plan.



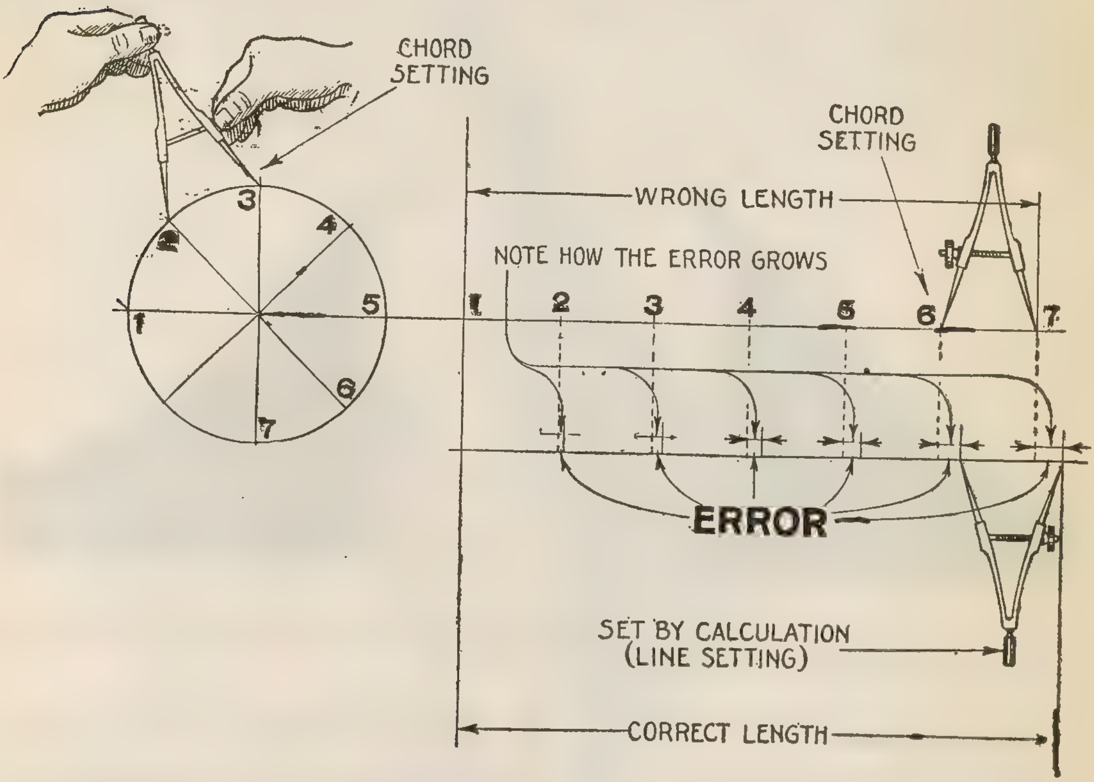
FIGS. 9,451 and 9,452.—Chord method of spacing.



FIGS. 9,453 and 9,454.—Method of setting dividers by calculation; line setting. See also fig. 9,163.

In the stretchout erect perpendiculars through the points 1,2,3, etc. and project over from elevation, points A,(B)(H), (C) G, (D) F, and E., giving points A,B,C,D,E,F,G,H,A. Draw a curve through these points which completes the stretchout. Note carefully in projecting over points from elevation, their location on stretchout. Thus point (B), is projected to perpendicular through 2, and point H, to perpendicular through 8; this is evident from the plan.

Where a large number of points are taken the length of the spacing of the point in stretchout may be obtained by setting the dividers by the



Figs. 9,455 and 9,456.—Comparison of chord and line setting of dividers showing magnitude of error due to its multiplication in spacing.

chord method as in fig. 9,451, but it should be understood that this is only an approximation and the stretchout will never be the full length no matter how many points are taken.

For precision, especially where only a few points are taken (as in. fig. 9,448) the dividers should be set by calculation, called line setting (figs. 9,453 and 9,454). A comparison of the two methods is shown in figs.

9,455 and 9,456. To illustrate the method of line setting suppose the diameter of the cylinder be 6 ins. and the 8 points be taken as in fig, 9,454. Then

$$\text{circumference} = 6 \times 3.1416 = 18.85 \text{ ins.}$$

that is, the length of the stretchout = 18.85 and the distance between points = 18.85 ÷ 8 = 2.36 ins. Draw a line and measure off accurately a distance LF = 18.85 ins.

Now set dividers to 2.36 ins. and make a trial spacing. The result obtained will probably be as on line A. Note magnitude of the error. Make additional trials as indicated on lines B,C,D, etc., until the true setting is obtained as on line LF. This method is also explained in more detail in fig. 9,163.

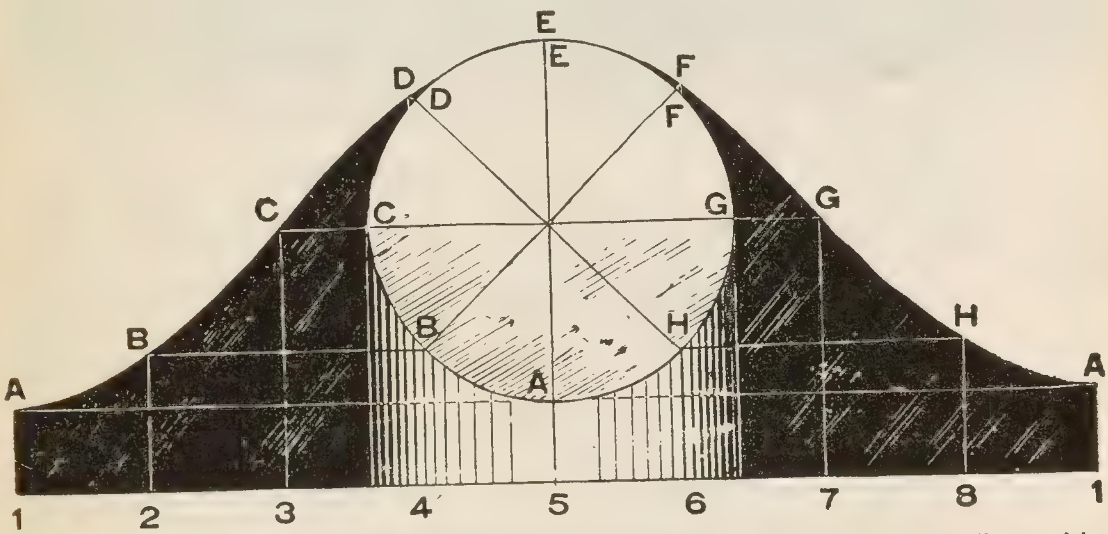


Fig. 9,457.—Pattern for cylinder (as obtained in figs. 9,448 to 9,450) in flat and rolled position showing its appearance in these positions.

Development of Patterns by Radial Lines.—For objects such as pyramids, cones, etc., whose elements converge toward a common point, the development of a pattern is made by the method of radial lines as illustrated in the examples following.

Example.—Develop a pattern for the sides of the pyramid shown in fig. 9,458.

First draw an elevation and plan as shown in figs. 9,459 and 9,460. By examination of the pyramid (fig. 9,458) it will be seen that the edges (H1, H2, H3, H4) are of equal length, and since these edges (which are elements of the surface) converge to a common point, their extremities in

the development will lie in an arc of which the common point or apex is the center. Since the elevation does not show the true length of the elements, revolve one element as H4, into the plane of the elevation. To do this, describe an arc through point 4, in plan with D4, as radius and where this cuts axis MS, at *s*, project up to H′, and draw HH′, which gives true length of the elements. Develop the pattern, take H′, as center and H′H, as radius describe arc LF.

Set dividers to distance of one side obtained from plan and space off points 1, 2,3,4,1 on LF. Connect these points with H′, and draw lines connecting points 1,2; 2,3; 3,4; 4,1. The figure thus obtained is the pattern required.

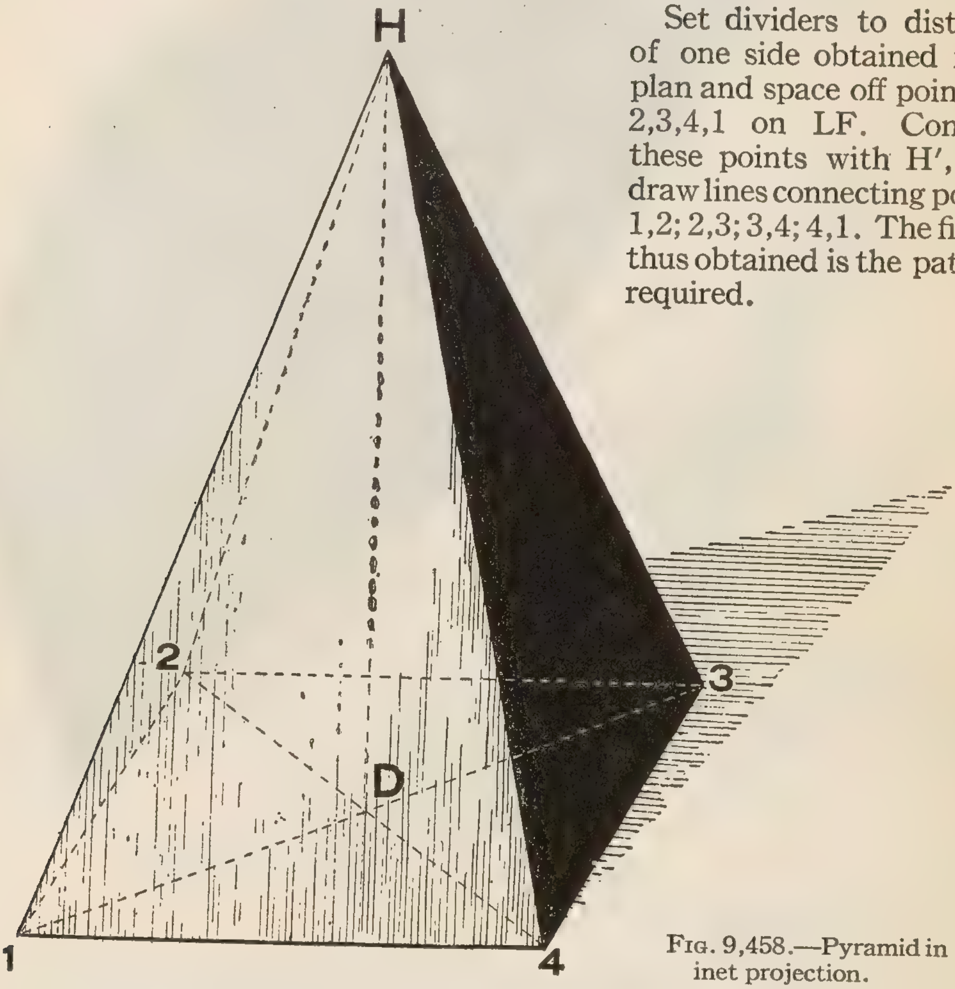


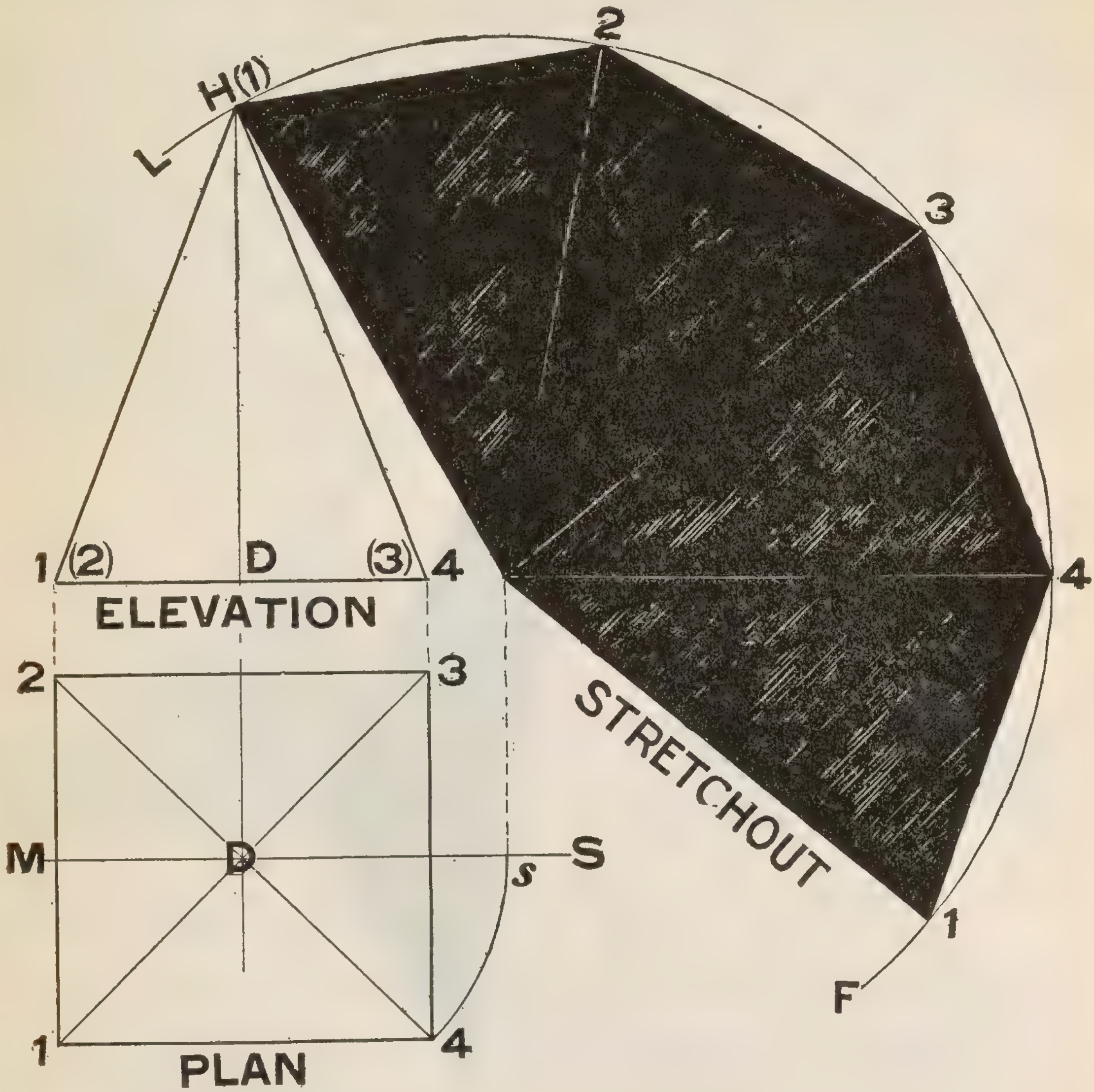
FIG. 9,458.—Pyramid in cabinet projection.

Example.—Develop a pattern for the slant surface of the oblique cone shown in fig. 9,461.

Draw elevation and plan as in figs. 9,462 and 9,463. The element H1, appears in true length in elevation and may be taken as the beginning of the pattern.

The other elements with exception of 5, do not appear in true length. Hence, revolve H′2, to MS, in plan and project up to 2′, in elevation, giving

H2′, as true length of H2. Similarly obtain H3′ and H4′, true lengths of H3 and H4. With H, as center and radius H1, describe arc L; with radius H2′, arc A; with radius H3′, arc R; with raduis H4′, arc F; with radius



Figs. 9,459 and 9,460.—Development of pattern ***by radial lines*** for the pyramid shown in fig. 9,458.

H5, arc G. Set compasses to common distance between elements in plan as distance between points 1 and 2. With dividers set to this distance and with 1 (in stretchout) as center describe arc *a*, cutting A at 2; with 2, as center, arc *r*, cutting R, as center; with 3, as center, arc *f*, cutting F at 4; with 4, as center, arc *g*, cutting G at 5. This gives points for half of the pattern of which the other half is similar, the points 6, 7 and 8, being obtained by

the intersection of arcs f', r', a', with F′,R,A. Join all the points by a curve and draw 1′H, thus completing the pattern.

Development of Patterns by Triangulation.—There are some forms of elementary surfaces so shaped that although straight lines can be drawn on them such straight lines when drawn

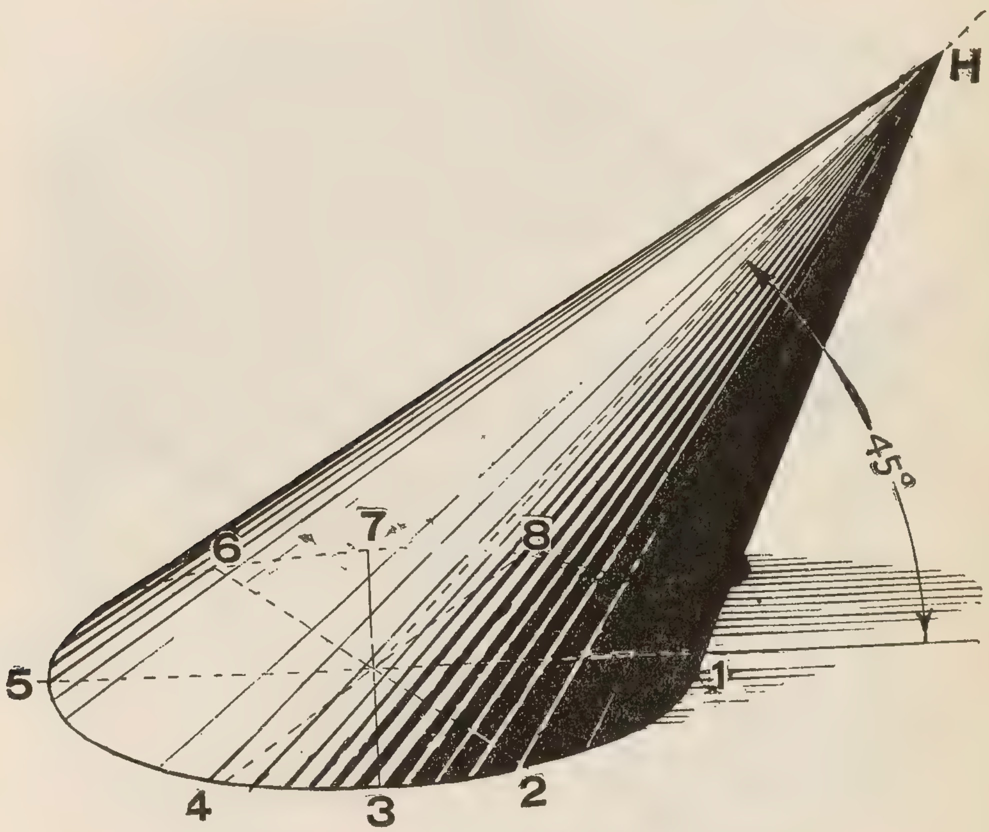


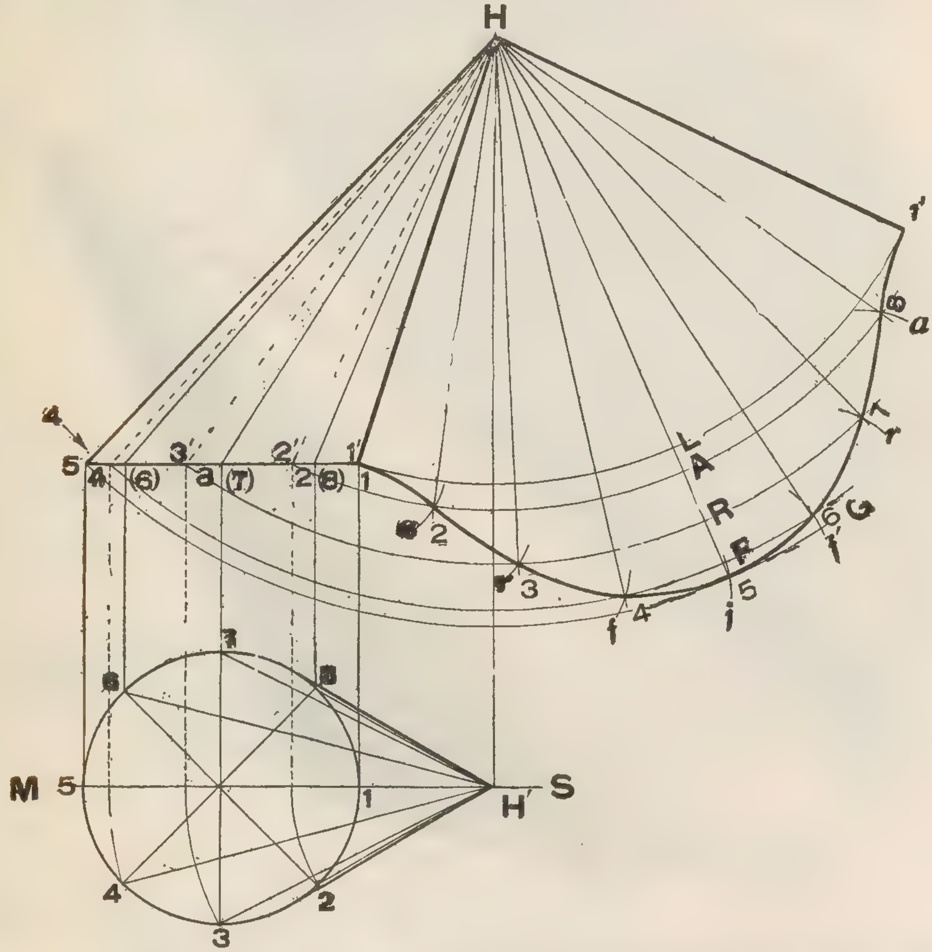
Fig. 9,461.—Oblique cone in cabinet projection.

would neither be parallel nor be inclined toward each other with any degree of regularity.

In developing a pattern for such surfaces the surface is divided up into a number of elementary triangles (hence the name *triangulation*). Next the true lengths of the sides of the triangles are found, and the triangles reproduced in the pattern.

Example.—Develop a pattern for the slant surface of the irregular elementary solid shown in fig. 9,464.

Draw elevation and plan as in figs. 9,465 and 9,467. Select any number of points on the bottom edge and the same number of similarly located points on the top edge. For simplicity only 8 points are taken on each edge (though in practice a greater number are taken).



FIGS. 9,462 and 9,463.—Development of pattern ***by radial lines*** for the oblique cone shown in fig. 9,461.

If points be taken for instance at the intersection of similar axes with the edges, they will be similarly located. These points are 1,3,5,7 for the bottom and A, C, E, and G, for the top. Determine the true lengths of the elements by constructing for each element a right angle triangle whose base is equal to its projection on the base or length in plan, and its altitude to the vertical height of the element in elevation. The hypotenuse of such triangle will then equal the true length of the element. To construct these

triangles continue over to right the top and base in elevation and the distance between these lines will equal common altitude of the triangles. Beginning with element A1, its true length appears in elevation, hence it is not necessary to construct a triangle to find its true length.

For the next element B1, set dividers to distance B1, in plan, and mark this distance on base line of triangle layout as *b*1. Draw perpendicular

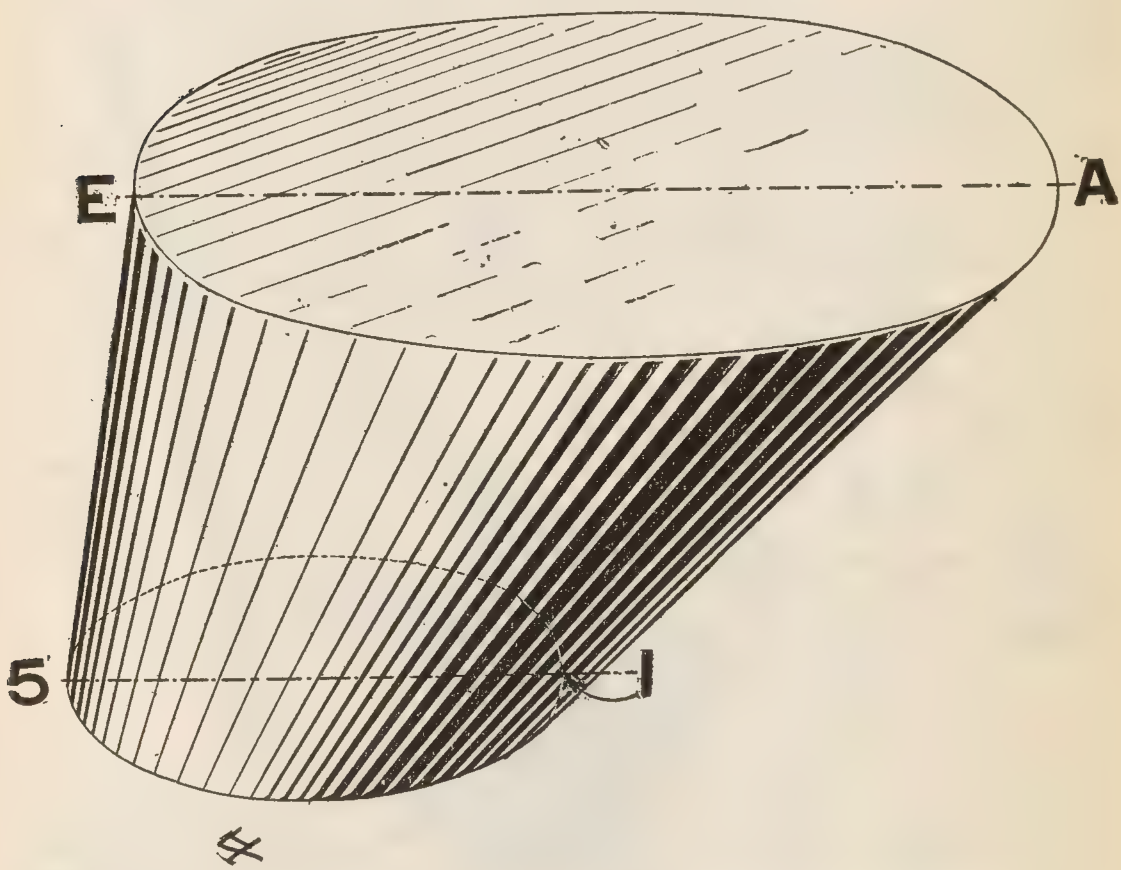


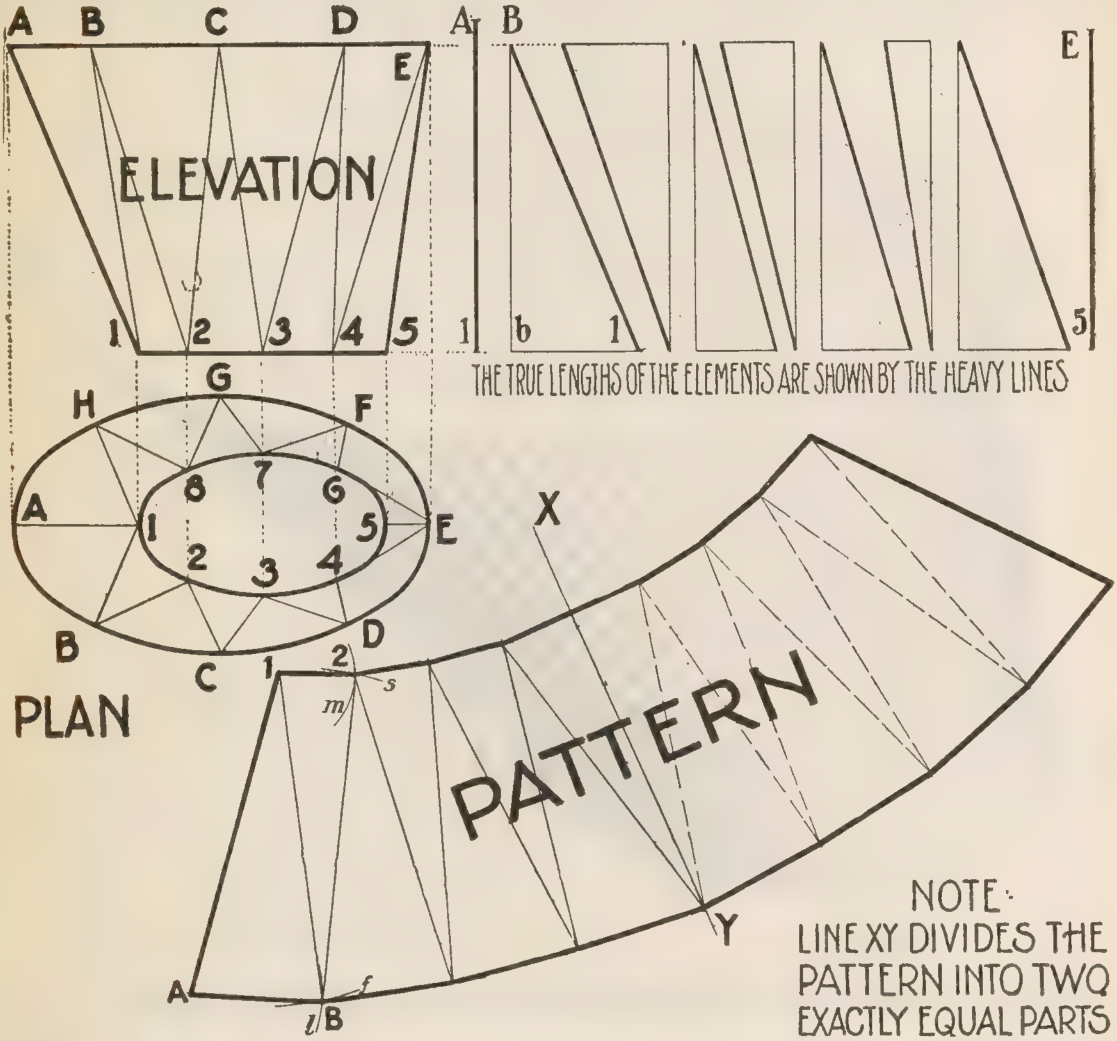
Fig. 9,464.—Irregular warped solid with parallel bases shown in cabinet projection.

*b*B, and join B1, thus completing the triangle. Its hypotenuse B1, then, is the true length of the element B1, which appears foreshortened in both plan and elevation.

In similar manner the true length of all the other elements are found. Next lay out the pattern, using the true lengths of the elements just found.

Begin laying out pattern by drawing A1 in true length.

With A, as center and radius equal to chord distance AB, in plan describe arc *l*, and with 1, as center and with radius equal to true length of of element B1, as found in the triangle layout, describe arc *f*, intersecting arc *l*, at B. Join A and 1, to B, thus completing the first triangle A1B.



FIGS. 9,465 to 9,468.—Development of pattern by ***triangulation*** for the irregular warped solid shows in fig. 9,464.

For the second triangle take point 1, of pattern as center and with radius equal to chord distance 12, in plan, describe arc *m*, and with B, as center and radius equal to true length of element B2, obtained from the triangle layout, describe arc *s*, intersecting *m*, at 2. Join 1 and B to 2, thus

completing the second triangle 1B2. Continue in same manner until the pattern is completed.

Example.—Develop a pattern for the slant surface of the irregular warped solid shown in fig. 9,469.

This is virtually the same problem as worked out in figs. 9,465 to 9,468 except that the top is inclined to the base. The same method is used and the drawings of each problem are similarly lettered. The only difference

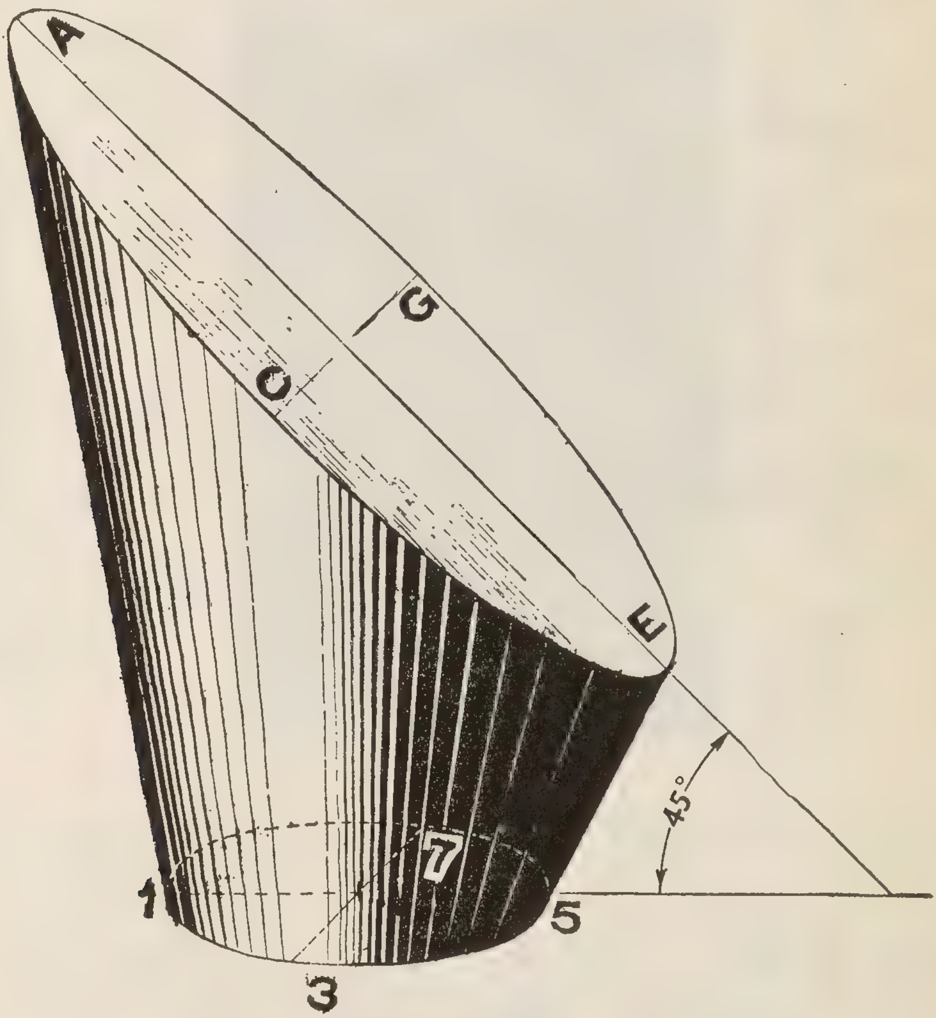


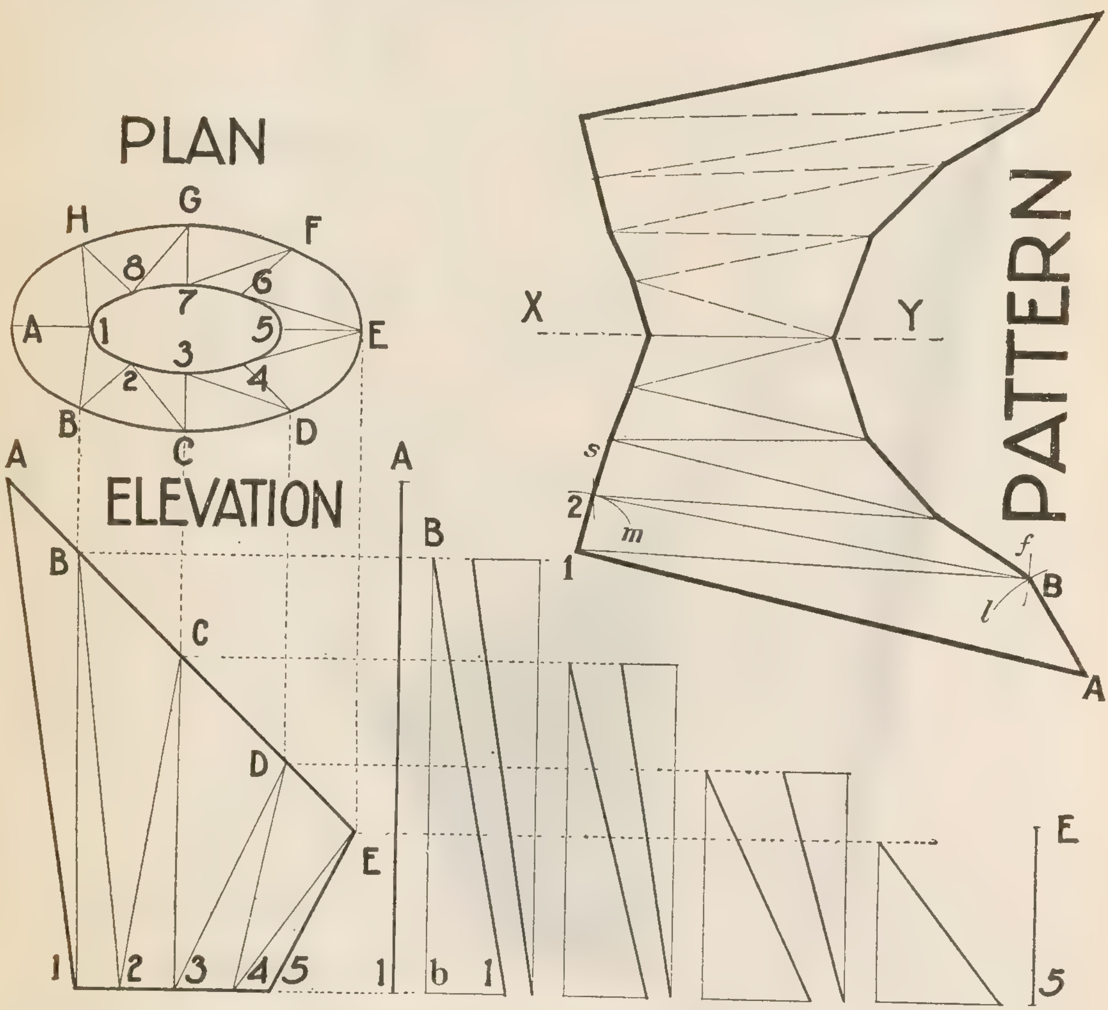
Fig. 9,469.—Irregular warped solid with inclined top shown in cabinet projection.

in laying out the lines is in the triangle layout. Here as will be seen in figs. 9,470 to 9,473 the triangles have different altitudes depending on the location of the points on the top edge.

Elements A1, and E5, appear in their true length, hence no triangles are necessary for these.

2. Warped Surfaces

A warped surface has been defined as one in which *a straight edge may be placed in contact only at a point*, as for instance the



FIGS. 9,470 to 9,473.—Development of pattern ***by triangulation*** for irregular warped solid shown in fig. 9,469.

sphere shown in fig. 9,466. It is not possible to develop a pattern that will fit such surface because the surface does not contain elements. Accordingly after developing a pattern

approximating the surface, it is necessary to *raise* the surface of the metal pattern by hammering to shape so that when the pattern is in position it will coincide with the warped surface of the solid. A sphere is a typical example of a warped surface and to avoid repetition, only part of it will be considered.

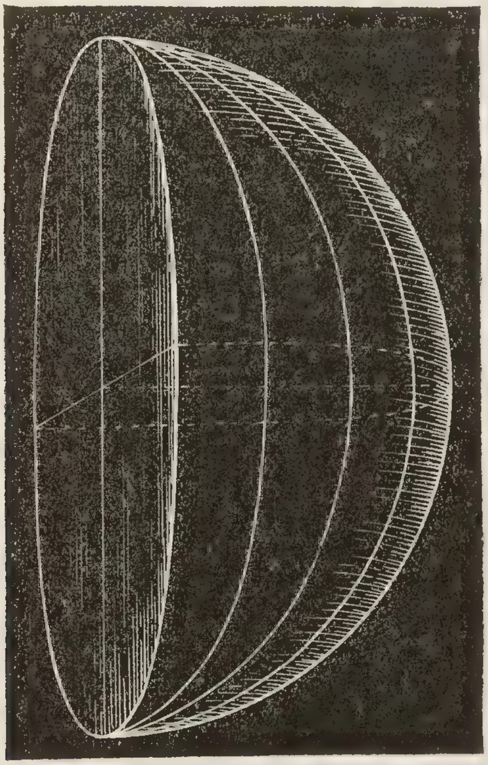


FIG. 9,474.—Hemisphere shown in cabinet projection.

Example.—Develop a pattern for the warped surface of a hemisphere or half-sphere.

The warped surface may be divided into as many *sections* as desired, the greater the number, the nearer will the pattern of each section approach to the shape of the warped surface when placed in position; that is, the less will be the amount of hammering necessary to *raise* the surface of the pattern so it will coincide with the warped surface. The warped surface may be divided into

1. Zones, or
2. Segments.

Case 1.*—Zone method.* In fig. 9,475, draw elevation of sphere and divide it into zones A,B,C. Zones A and B, will be frustums of cones and

C, a cone. Continue slant surface of frustum A, till it intersects the axis at H′, giving radius center for frustum A. With H′, as center describe the two arcs M and S.

Draw end view which gives the boundaries of the zones. In end view rectify arc 12, and space off on arc S, the points 1, 2, 3, 4 and 1. At 1, draw radial line connecting M and S, thus completing pattern for frustum A.

The patterns for frustum B, and cone C, are obtained in a similar way, no further explanation being necessary.

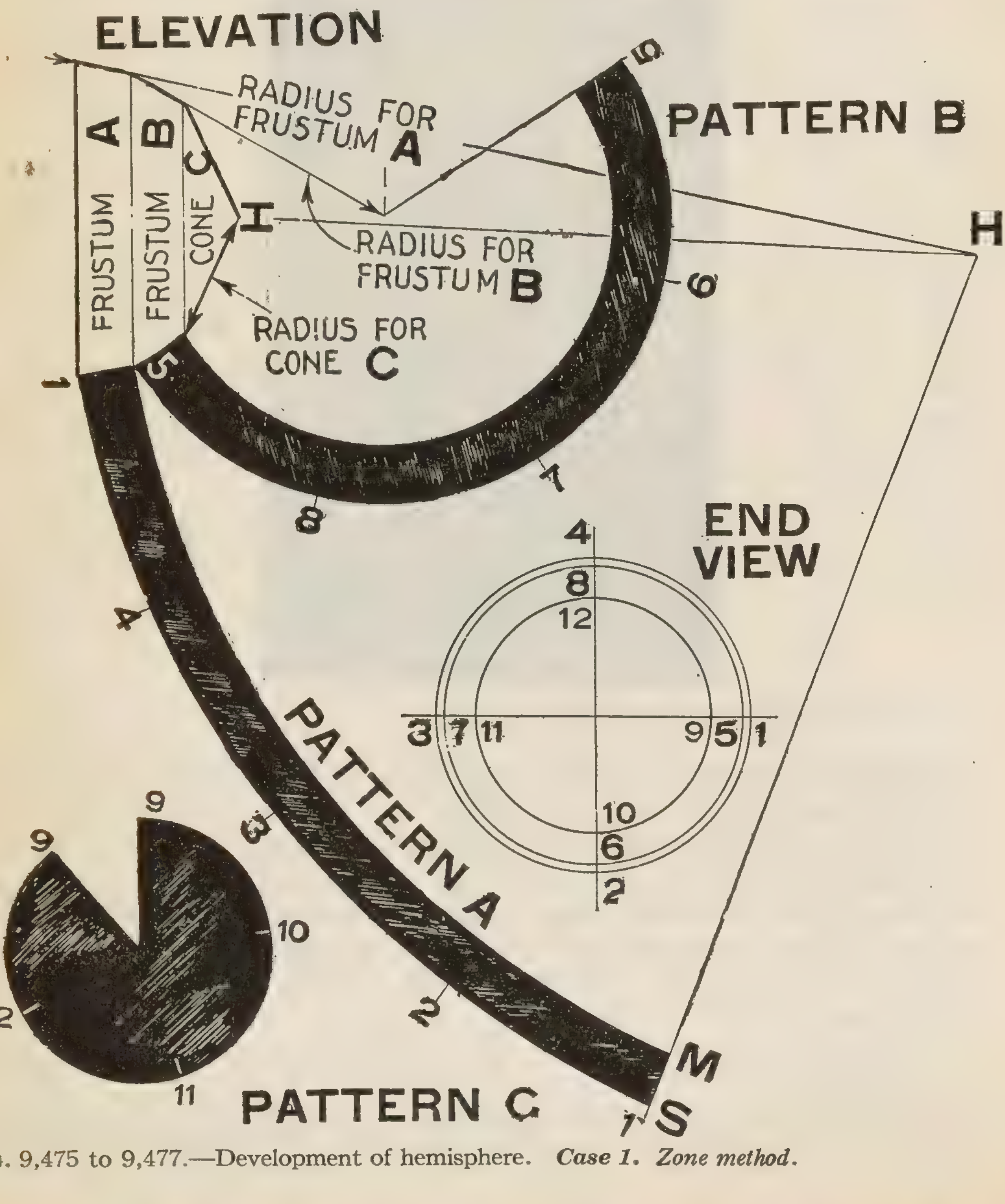
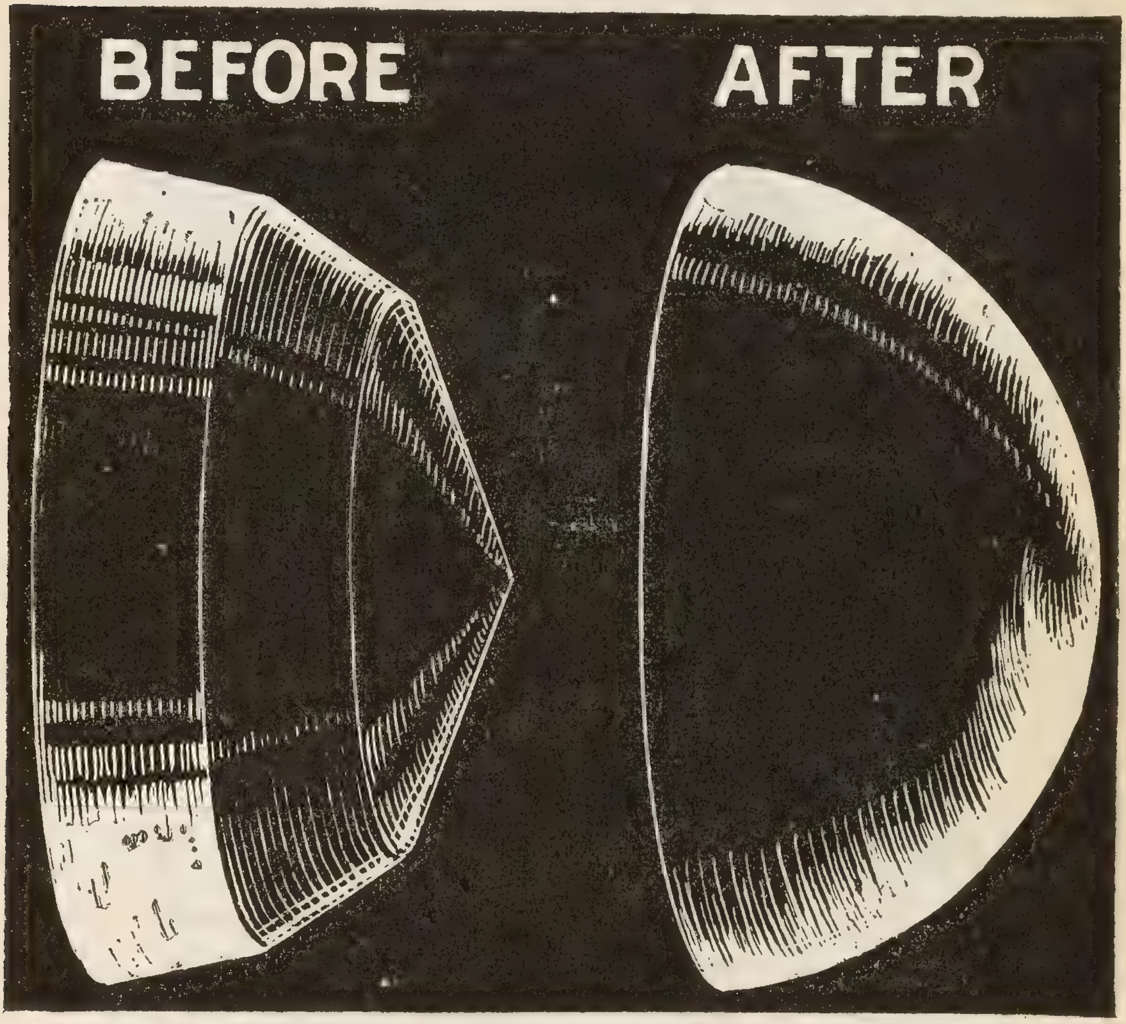


FIG. 9,475 to 9,477.—Development of hemisphere. *Case 1. Zone method.*

Case 2.—*Segment method.* Fig. 9,480 shows appearance of ¼ of the hemisphere which is divided into two segments. The shaded surface 1H2 being one of these sections. It is only necessary to develop a pattern for one section as all the others are of the same shape.

In fig. 9,481 which shows the same portion of the hemisphere, partly



FIGS. 9,478 and 9,479.—Appearance of pattern for hemisphere before and after hammering or raising to the warped shape of the hemisphere. ***Case 1. Zone method.***

in cabinet projection and partly in elevation, draw zone circles F and L, spaced as shown.

In plan draw 1H2, projection of the segment for which a pattern is to be developed. Project into plan points *l* and *f*, and describe zone L and F′, which is the projection in plan of L and F, in elevation.

To develop the pattern, draw an axis HD. Rectify arc H*h*, and mark off the rectified length as H*h*, on pattern. With H as center, describe arc through *h*, and also arcs L and F, dividing H*h* into three equal parts. In pattern lay off 1 2 equal to 1 2 in plan; 63, equal to 63, in plan; 54, equal to 54 in plan. Draw through the points thus obtained curves connecting H, to 1 and 2, thus completing the pattern.

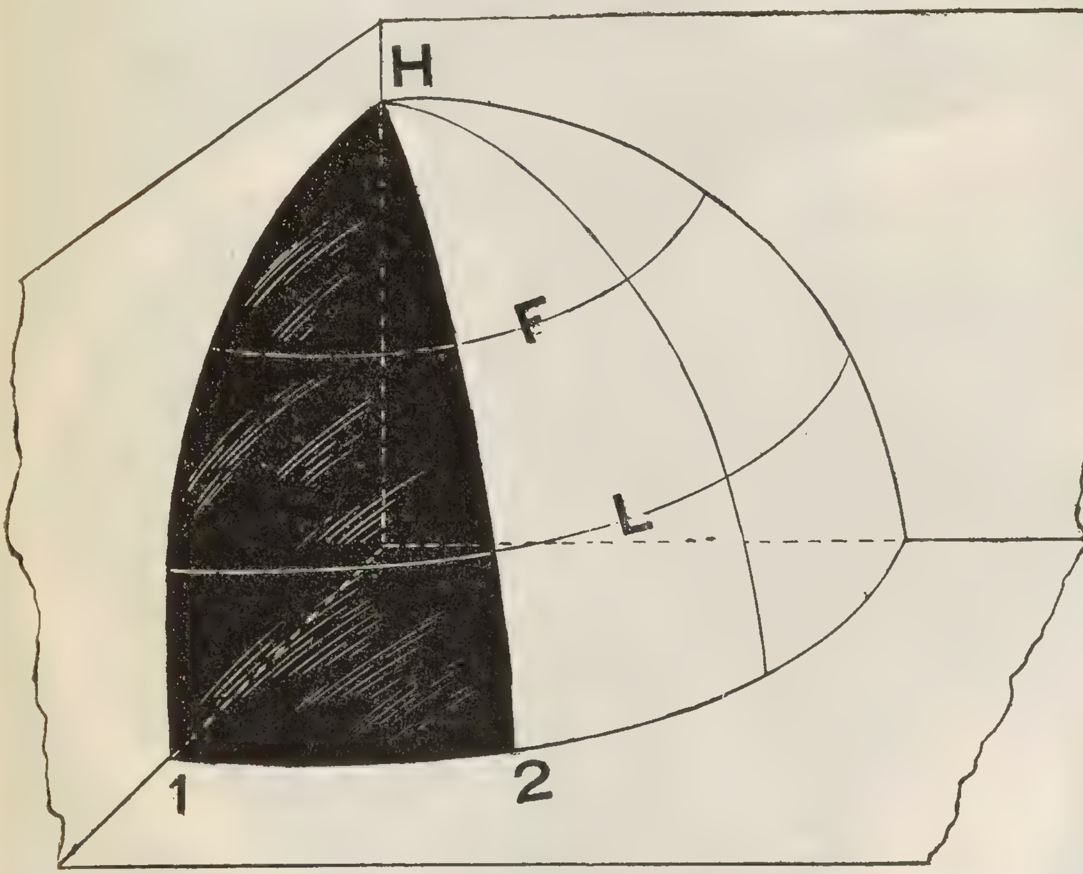
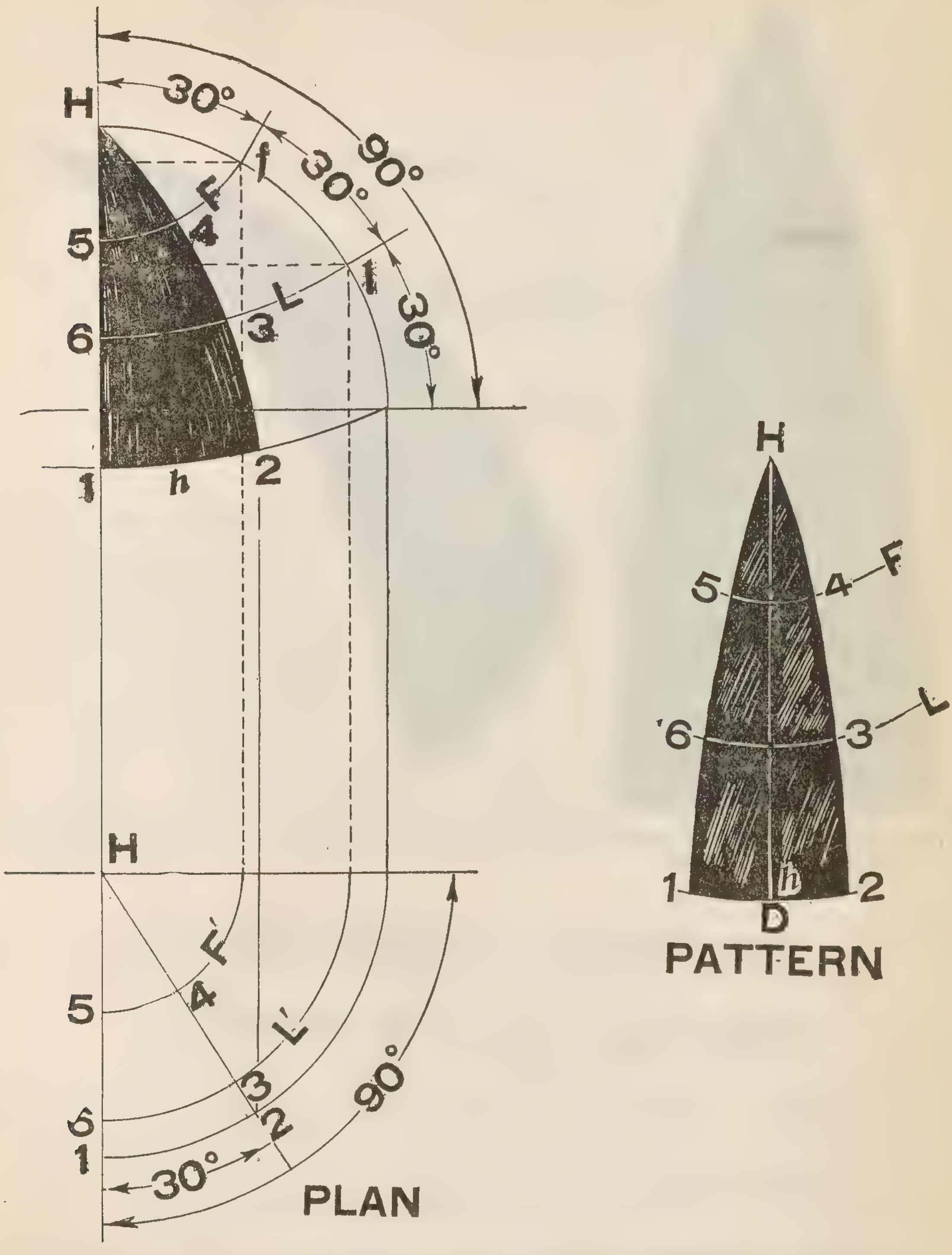
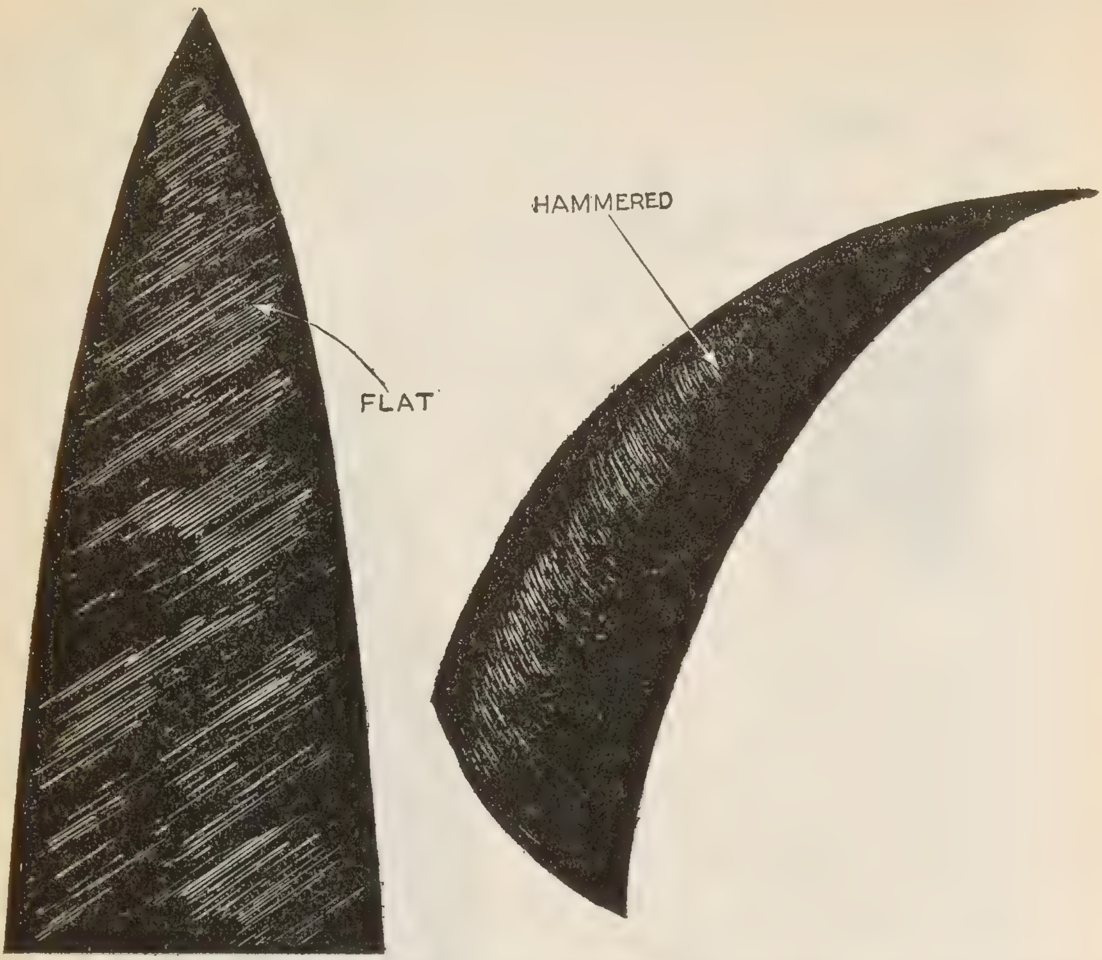


FIG. 9,480.—Quadrant of a hemisphere showing surface divided into segments.

NOTE.—***The Sphere.***—A semi-circle revolving about its diameter generates a solid called a *sphere*. Every section of a sphere made by a plane is a circle. The circle is called a *great circle* if the plane passes through the center, a *small circle* in all other cases. The part of a sphere contained between two parallel planes is called a *spherical segment*, and the part of the surface of the sphere contained between the planes is called a *zone*. The circular sections made by the planes are called the *bases* of the segment, and the distance between them is called the *height* of the segment or zone. A single plane divides a sphere into two parts called *segments of one base*, and the surface into two parts called *zones of one base*. A great circle divides a sphere into two equal segments called *hemispheres*. The portion of a sphere generated by the revolution of a circular sector about one of its radii is called a *spherical sector*.



FIGS. 9,481 to 9,483.—Development of patterns ***by approximation*** for a hemisphere or warped surface. ***Case 2.*** *Segment method.*



FIGS. 9,484 and 9,485.—Appearance of pattern for hemisphere before and after hammering. *Case 2. Segment method.*

CHAPTER 148

Sheet Metal Work

Developments

In this chapter numerous examples are given, further illustrating each of the methods explained in the preceding chapter so that the student may obtain proficiency in developing patterns for objects having *elementary*, or *warped* surfaces.

The author is indebted to Dr. John Weichsel, professor of drawing and sheet metal work, for the problems in this chapter. They are arranged in groups under each method of development, although in some cases more than one method is employed.

1. Elementary Surfaces

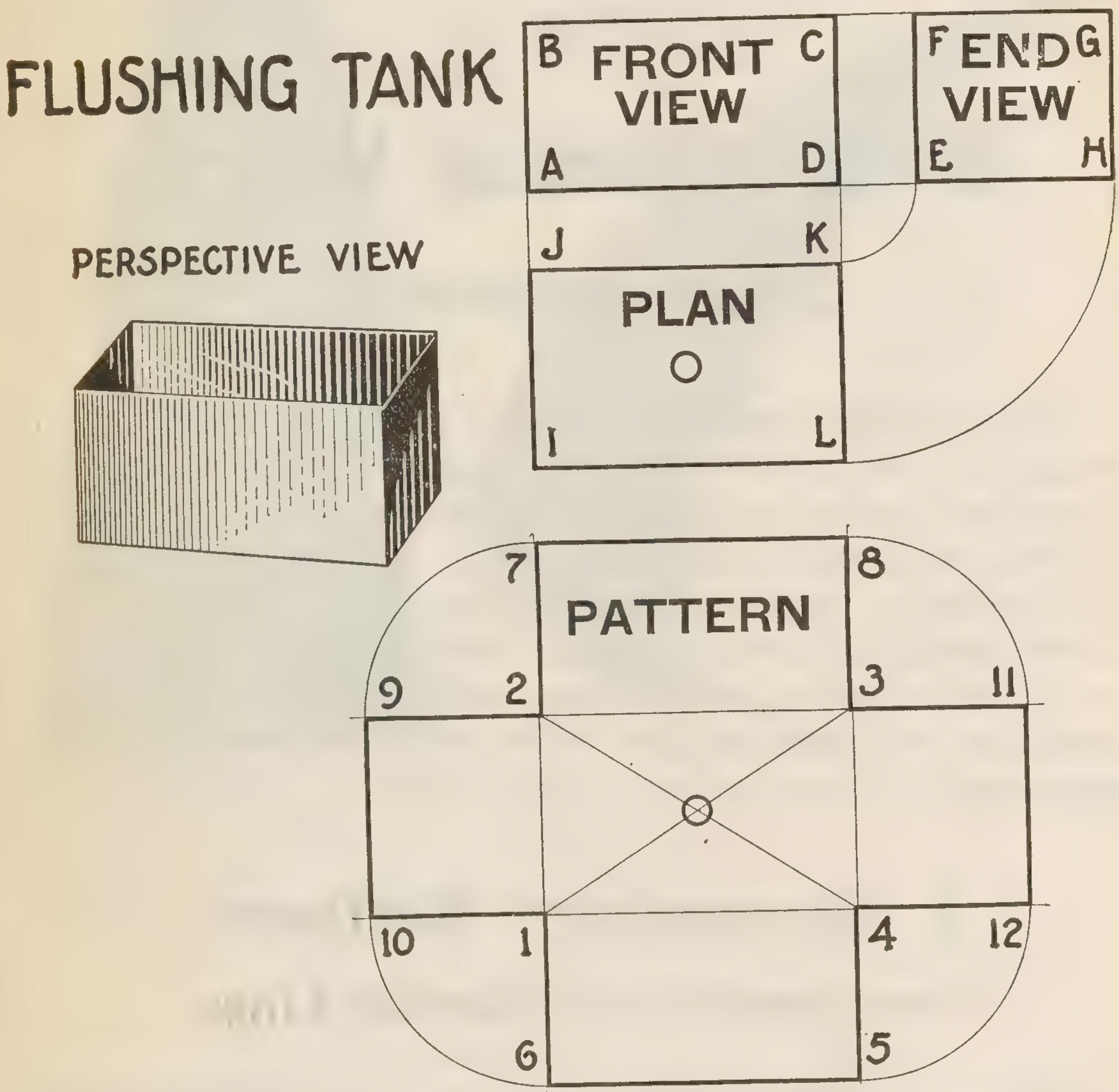
Development by Parallel Lines

Problem 1.—Pattern for flushing Tank. Figs. 9,486 to 9,490.

Draw the plan, front and end views of the required tank, full size, taking care to make all angles exactly right angles (90°).

The end view is not necessary for developing the pattern but is given just for practice in orthographic projection.

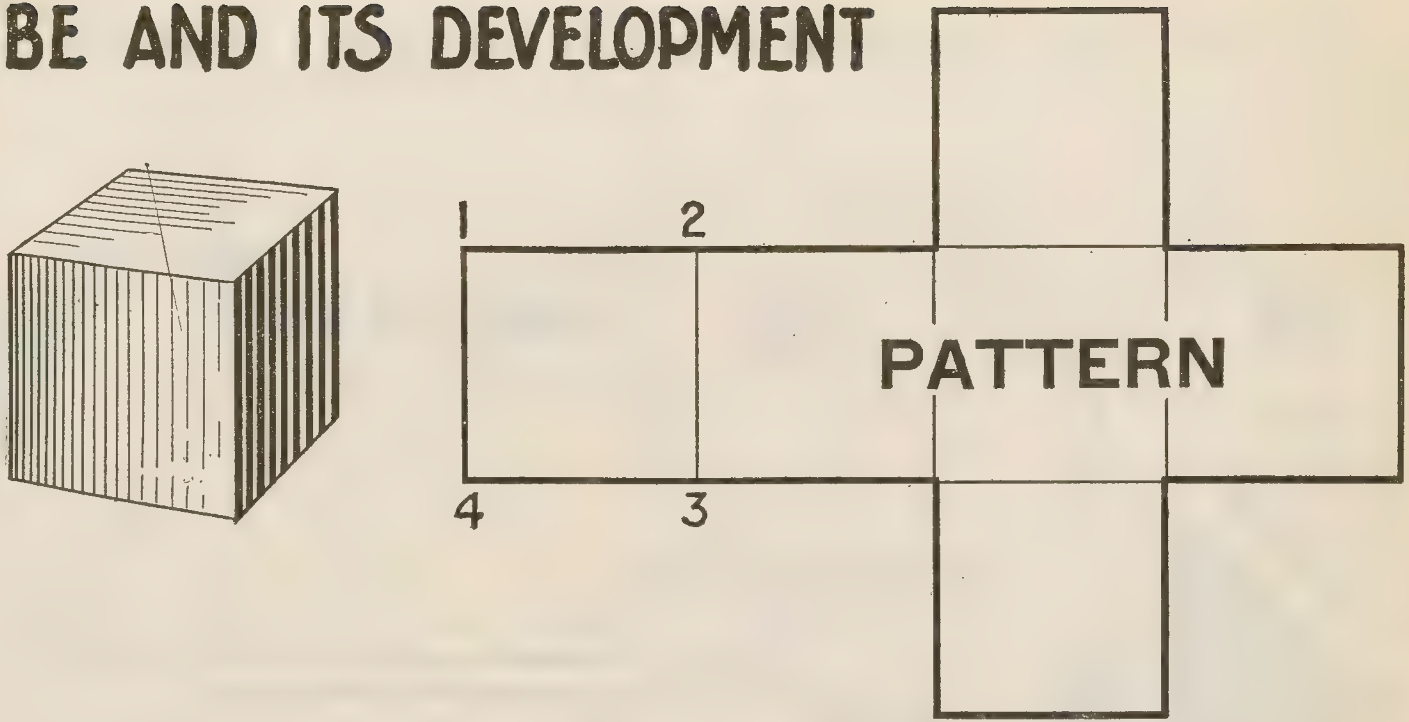
In developing the pattern, first lay out the rectangle 1 2 3 4, exactly equal to the plan IJKL. This rectangle will provide the bottom part of the tank. Extend the four lines of this rectangle, indefinitely, upward and downward, also to right and to left. Then set the dividers to a distance AB, equal to the height of the tank, and with this distance as radius, de-



FIGS. 9,486 to 9,490.—*Problem 1.* Flushing tank and development of its pattern.

scribe arcs at the four corners of the rectangle, using the points 1,2,3,4 as centers. These arcs cut off the extended lines of the bottom part, thus giving the rectangles 6 1 4 5, for the front part; 2 7 8 3, for the rear part; 1 10, 9 2, for the left and 4 3 11, 12, for the right end of the tank.

CUBE AND ITS DEVELOPMENT

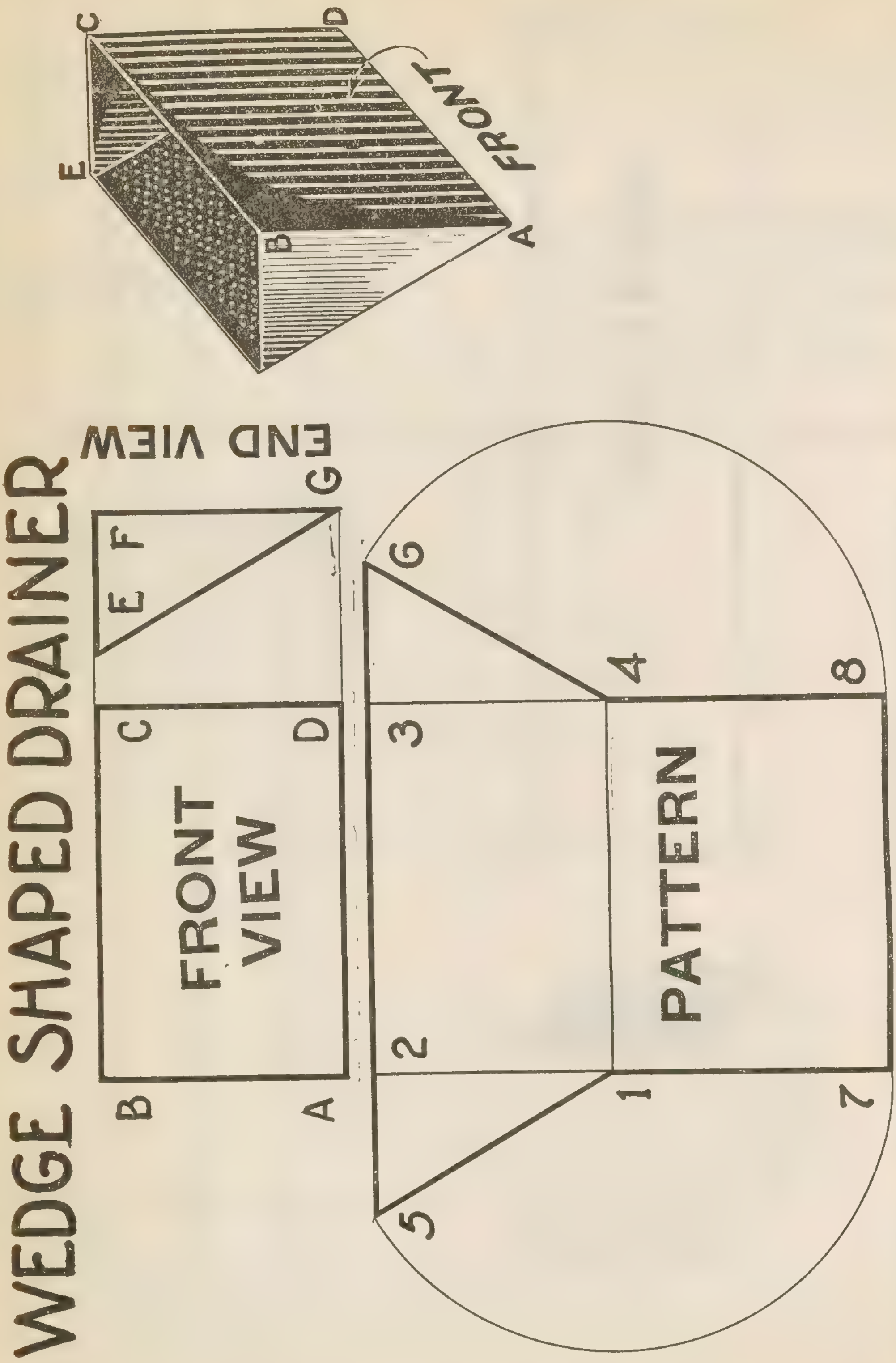


Figs. 9,491 and 9,492.—***Problem 2.*** Cube and development of its pattern.

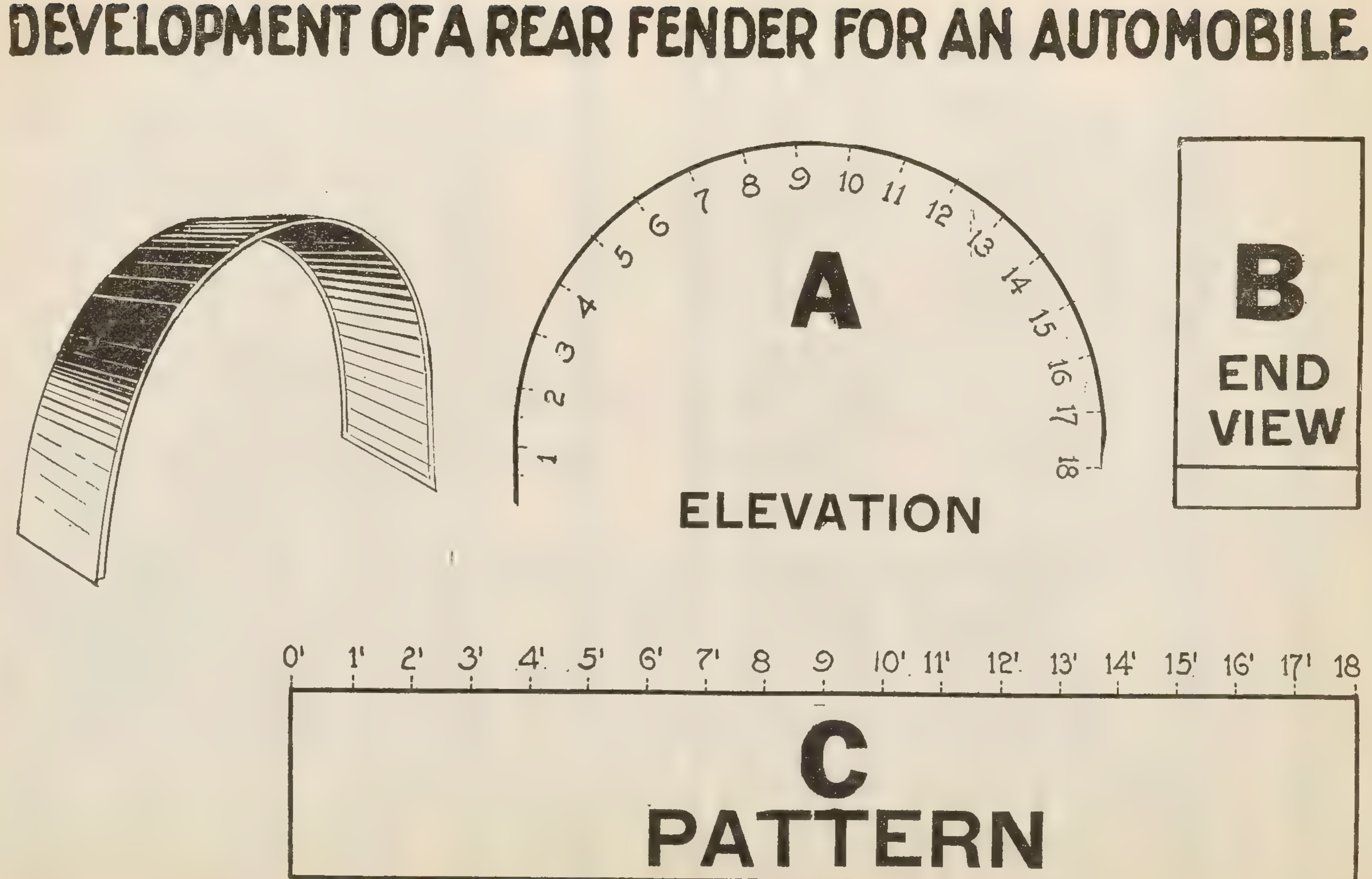
Additional strips of stock should be added along the edges 6 1, 2 7, 3 8, and 4 5, for laps of proper width.

The point of intersection of the two diagonals in the bottom part furnishes the center of the hole for the flushing pipe.

There being no cover to this tank, its pattern is made up of only five rectangles. When a pattern is to be made for a closed, square container, six rectangles are required, as in problem 2.



FIGS. 9,493 to 9,496.—*Problem 3.* Wedge shaped drainer and development of its pattern.



FIGS. 9,497 to 9,500.—*Problem 4.* Rear fender for automobile and development of its pattern.

Problem 2.—Pattern for a cube. Figs. 9,491 and 9,492.

This is virtually the same as problem 1 except the additional rectangle 1 2 3 4, forming the top or cover, considering the cube as a container with a cover.

Problem 3.—Pattern for a wedge shaped drainer. Figs. 9,493 to 9,496.

Draw front and end views as in figs. 9,493 and 9,494.

All the angles in the front view should be right angles or 90°. In the end view, the angle at the corner F, is a right angle. To lay out the required pattern, draw the rectangle 1 2 3 4, exactly equal to the front view A B C D. Extend the line 2 3, to right and to left, also extend downward the lines 1 2 and 4 3.

Set dividers to a distance equal to the oblique line G E. With this distance as radius, describe the arc 7 5, with point 1 as center. Then describe the arc 8 6, with point 4 as center. These arcs determine the rectangle 7 1 4 8, for the front part of the drain as well as the triangular parts 1 5 2 and 4 3 6, for the two ends of the drain.

Additional strips of stock should be added along the edges 1 5 and 4 6, for laps of a suitable width.

Problem 4.—Pattern for a rear fender for an automobile. Figs. 9,497 to 9,500.

As now manufactured, a full crowned fender is made with the aid of dies and rolls and when thus formed the shape presents a warped surface.

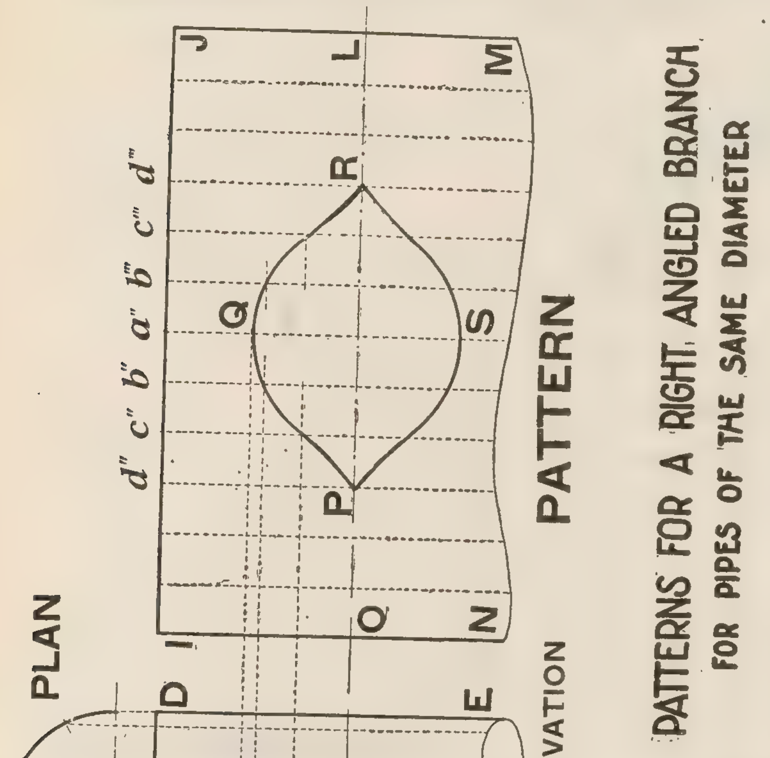
The fender here considered has an elementary surface. The body of the fender is provided with a flange for wire and beads, a rib being wired into the fender.

The development here described refers to the body of the fender. At A, the profile of the fender is divided into a number of equal parts, marked 1,2,3, etc. The width of the fender body being given at B, the pattern is made up of a rectangular strip, shown at C, whose width is equal to that of B, and the length, to the combined length of all the divisions into which the profile at A, is divided.

In rectifying the profile to obtain the length of the pattern, chord distances should not be taken but the line method used as explained in figs. 9,453 and 9,454.

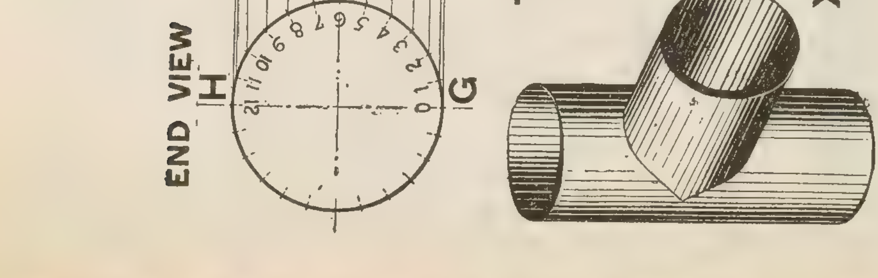
Problem 5.—Patterns for a Tee pipe. Figs. 9,501 to 9,506.

The problem involves the development of two intersecting cylinders, of equal diameters. The solution here given is the more important because it applies to a large class of elbows and other objects composed of intersecting cylinders. The method here used, may also be used where the intersecting cylinders are not of the same diameter.



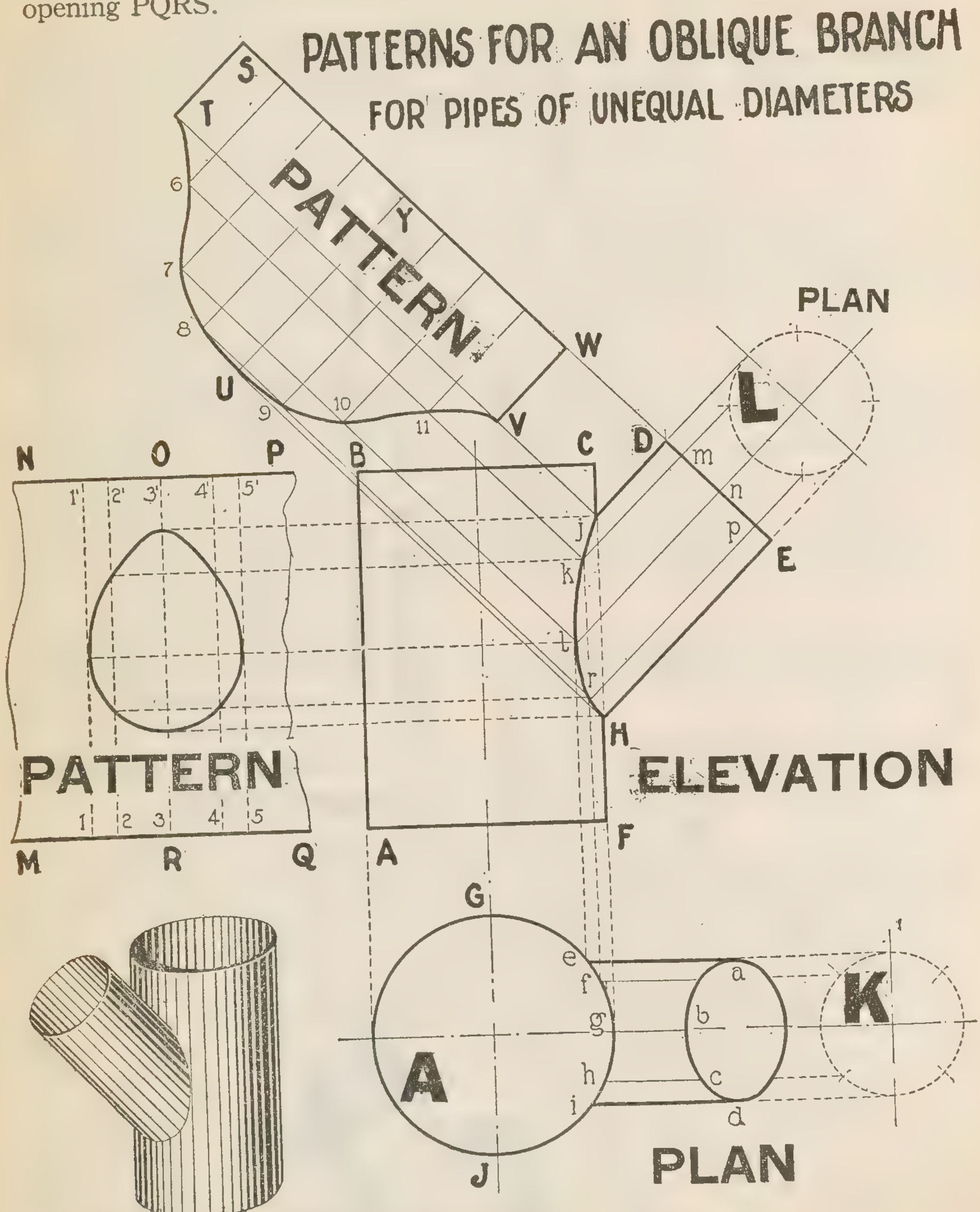
A hole must be cut in the veritcal or *run* pipe to provide an opening of suitable shape for the *branch* pipe and the end of the branch pipe must be shaped to fit the opening in the run.

NIJM, shows the development of the run pipe. The length IJ, is that of the circumference of the pipe, half of which is shown in the plan. The equally measured divisions on this circumference are put together to make up the line IJ. At right angles to this line, the lengthwise edges of



Figs. 9,501 to 9,506. —*Problem 5.* Tee pipe with run and branch of same diameter, and development of its patterns.

the development of the run pipe are shown by the lines IN, and JM. Only a part of the length of this pipe is developed, the part around the required opening PQRS.



FIGS. 9,507 to 9,513.—*Problem 6.* Y branch with run and branch pipes of unequal diameters and development of its patterns.

From the points of division in the plan, the longitudinally drawn projecting lines furnish on the joint line a′d′, the points a′, b′, c′, d′. From these, another series of projecting lines is drawn to the development, intersecting the longitudinal lines on the development which start from the points d″, c″, b″, a″, b″, c″, d″, thus giving points defining the outline of the opening PQRS as clearly shown.

In a like manner the other pattern, Z,T,U,Z′ is obtained from A,B,*a′*,*b′*,*c′*, *d′*. The circumference of the branch pipe GH, is divided at the points 0,1,2,3, etc., into equal parts. All these divisions are laid down, together, on the line ZT, so that the length ZT, is equal to the entire circumference of the branch pipe.

The procedure for the tracing of the outline Z′YWVU is the same as for the opening PQRS, it is clearly shown by the lines.

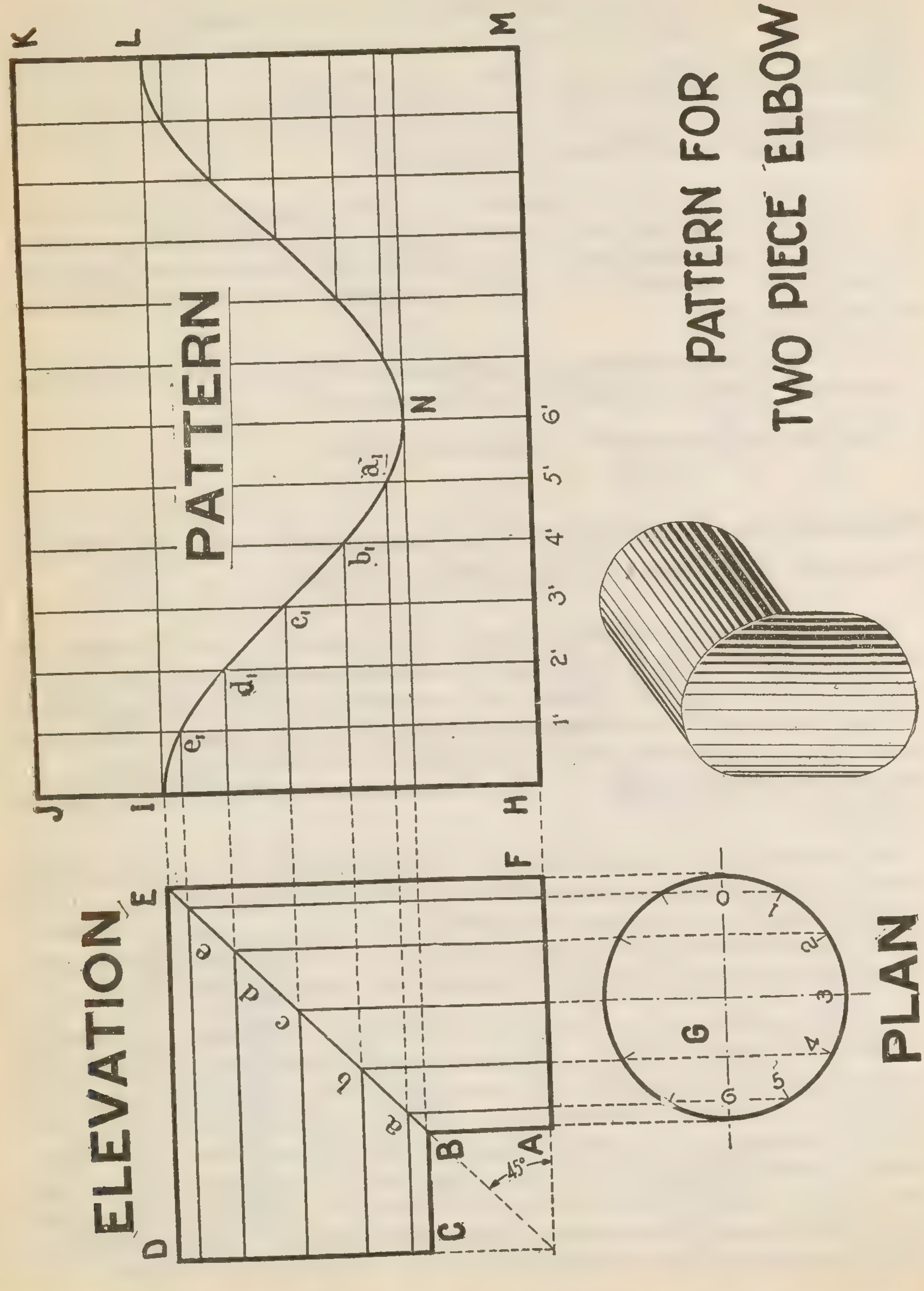
The patterns do not show any laps for joints.

Problem 6.—Patterns for a Y branch with run and branch of unequal diameters. Figs. 9,507 to 9,513.

Draw plan A, then draw the outlines of the elevation ABC*j*DEHF. To these outlines the curved joint edge between the main pipe and the branch may be added as follows: Divide the circumference of the branch pipe given at K, and also at L, into a number of equal parts and through the division points pass parallels along the branch pipe in the plan and elevation. In the plan A, these parallels cut the circumference of the run in the points *i*,*h*,*g*,*f*,*e*.

On the obliquely situated branch in the elevation B, the parallels should be drawn so as to pass for some distance into the elevation of the run. Then draw vertical projection lines from the points *i*,*h*,*g*,*f*,*e*, into the elevation of the run intersecting in the points H,*r*,*l*,*k*,*j*. These points when joined, give the view of the intersection between the branch and run pipes.

Now, proceed to lay out the pattern VUTSW, for the branch. Extend the end line DE, of the branch, indefinitely, toward the desired pattern and upon this extended line, make WS, equal in length to the circumference of the branch. At every division point, erect a perpendicular to WS, thus dividing the space for the pattern into a number of elementary parts. Now, from the points H,*r*,*l*,*k*,*j* (on the elevation) project a number of lines upon the pattern, parallel to the stretched out line SW. These projection lines cut the elementary lines on the pattern in the points T,6,7,8,U,9,10,11, V and the points in the curved outline of the pattern of the branch.



FIGS. 9,514 to 9,517.—*Problem 7.* Two piece elbow and development of its patterns.

The run pipe has to be cut out on an oval line to receive the branch. For the plotting of this oval on the pattern, draw the short part MNPQ, of the development of the run. In the middle of this, erect the perpendicular center line RO. Starting from this line, set off to left, the distances 32 and 21 respectively equal to *gf* and *fe* (in plan) and do the same in opposite order, to the right of the center line, so that 34, equals 23, and 45, equals 21.

Through the points 1,2,3,4,5 draw the vertical elements 11′, 22′, 33′, etc.

In the elevation, project points *j*,*k*,*l*,*r*, H, horizontally over to pattern of run. These horizontal projection lines cut the vertical elements 11′, 22′, etc., in a series of points, which, when joined, give the oval shape of the hole that is to be cut in the main pipe. Add to the patterns thus obtained proper lap for joints.

Problem 7.—Patterns for a two-piece elbow. Figs. 9,514 to 9,517.

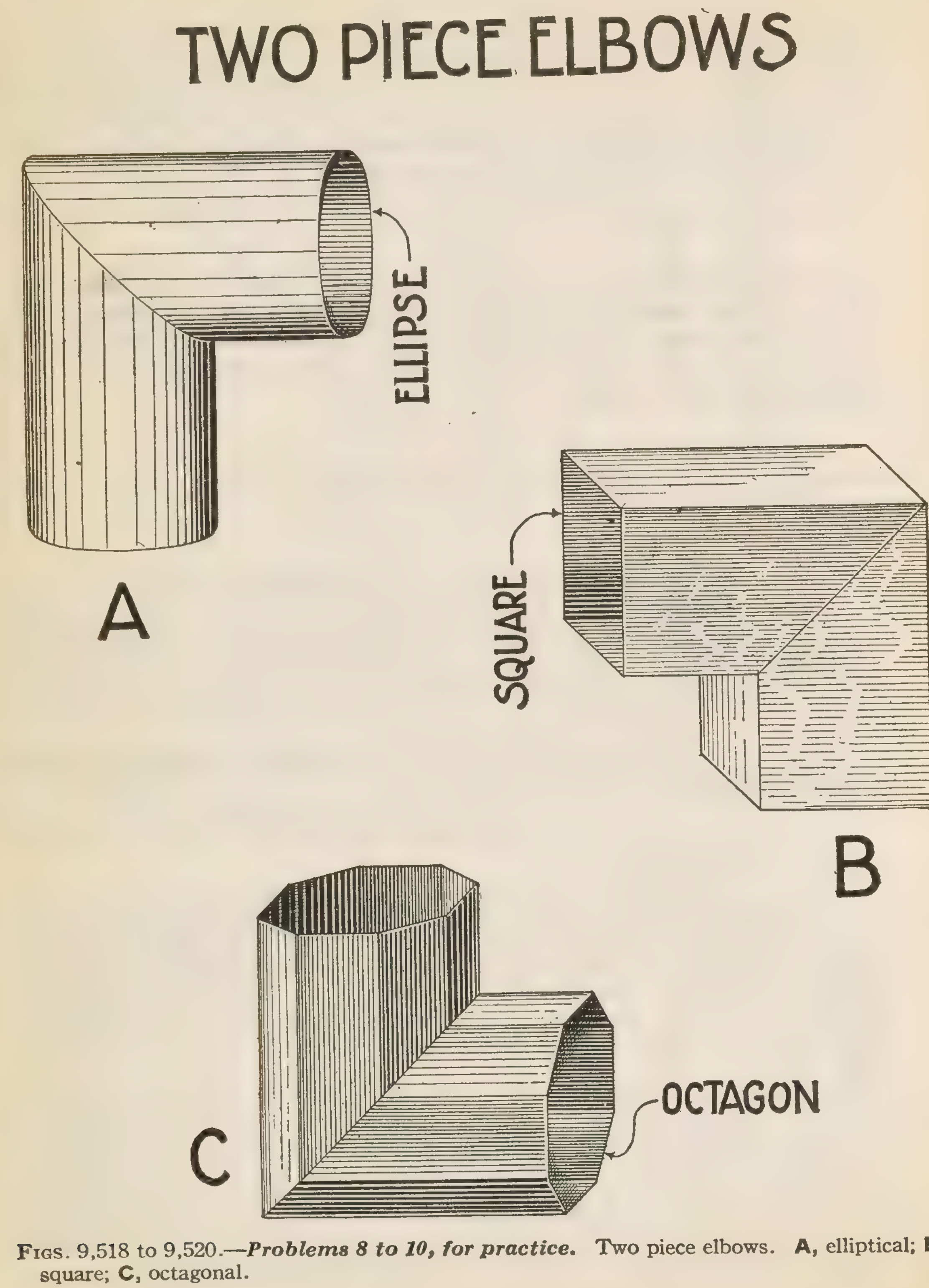
A two piece elbow for round pipes may be imagined to have been made up of two adjoining parts of one pipe that was cut at a miter of 45°. Hence, the patterns for the two halves of the elbow may be obtained first by developing the whole pipe of which the elbow parts are to be derived, and secondly, by dividing this development into two portions, in a suitable manner.

In the elevation, ABEF, is one part of the elbow and the other part BCDE, is identical to the first part.

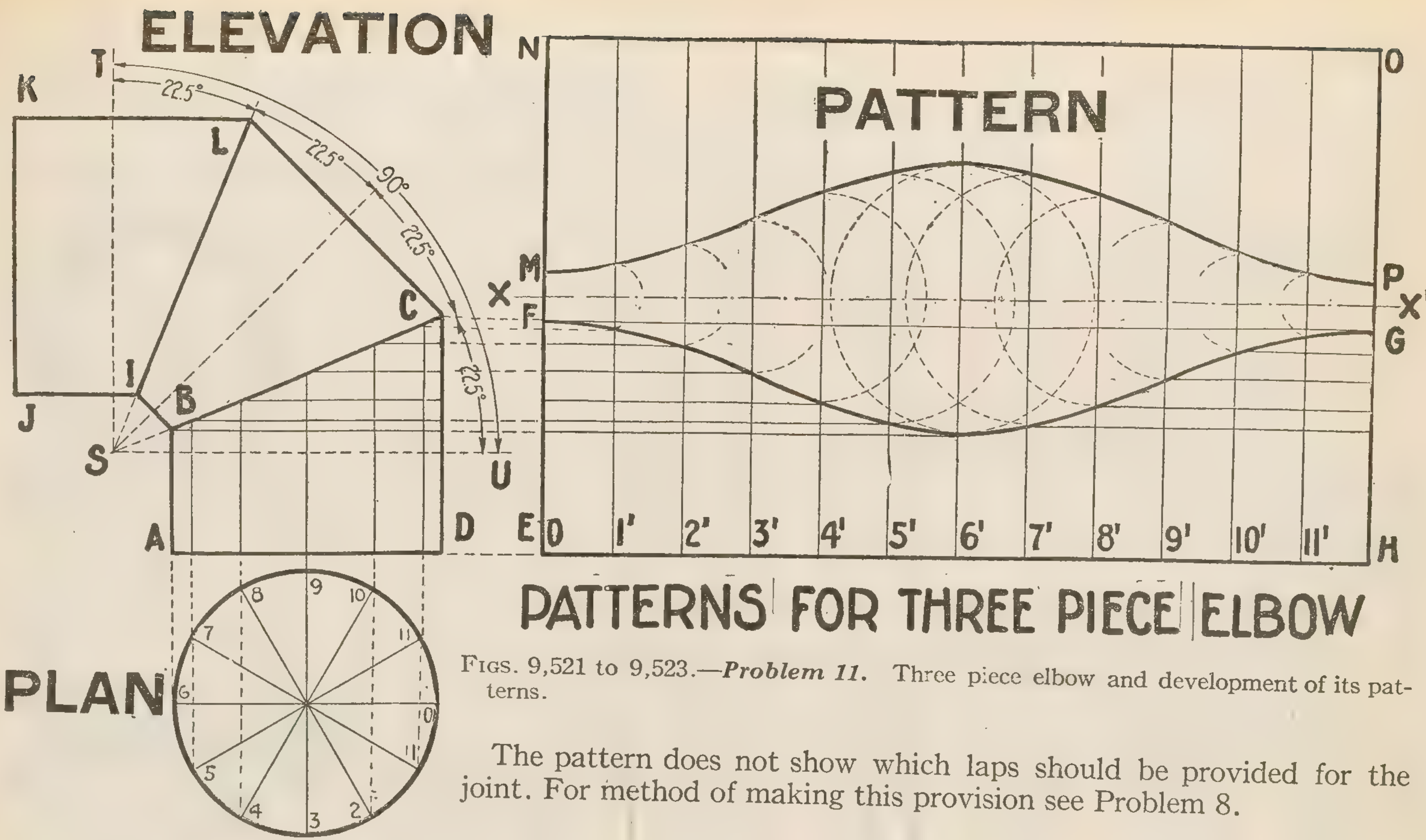
In the plan is shown the circumference of the elbow with a convenient number of equal divisions.

In the pattern development, HJ, is taken equal to AB + FE (in elevation). HJ, then represents the length of the single pipe that is to furnish the two component parts of the elbow. Hence develop the cylinder whose length is HJ, in the rectangle HJKM, wherein the divisions upon HM, are reproductions of the divisions on the circumference shown in plan, so that HM, is equal to the stretched out circumference.

Vertical or elementary lines (1′2′3′ etc.) are drawn from the points just obtained. Project point 1,2,3, etc., in plan to cut the miter line EB (in elevation) in points B,*a*,*b*,*c*, etc., whence, in turn, horizontal projecting lines are drawn to intersect the elementary lines upon the development in the points N, *a*,*b*, etc., thus giving the curve IN, as well as its counterpart NL. This curve divides the development into the two halves of which the elbow is to be made up.



FIGS. 9,518 to 9,520.—***Problems 8 to 10, for practice.*** Two piece elbows. **A**, elliptical; **B**, square; **C**, octagonal.

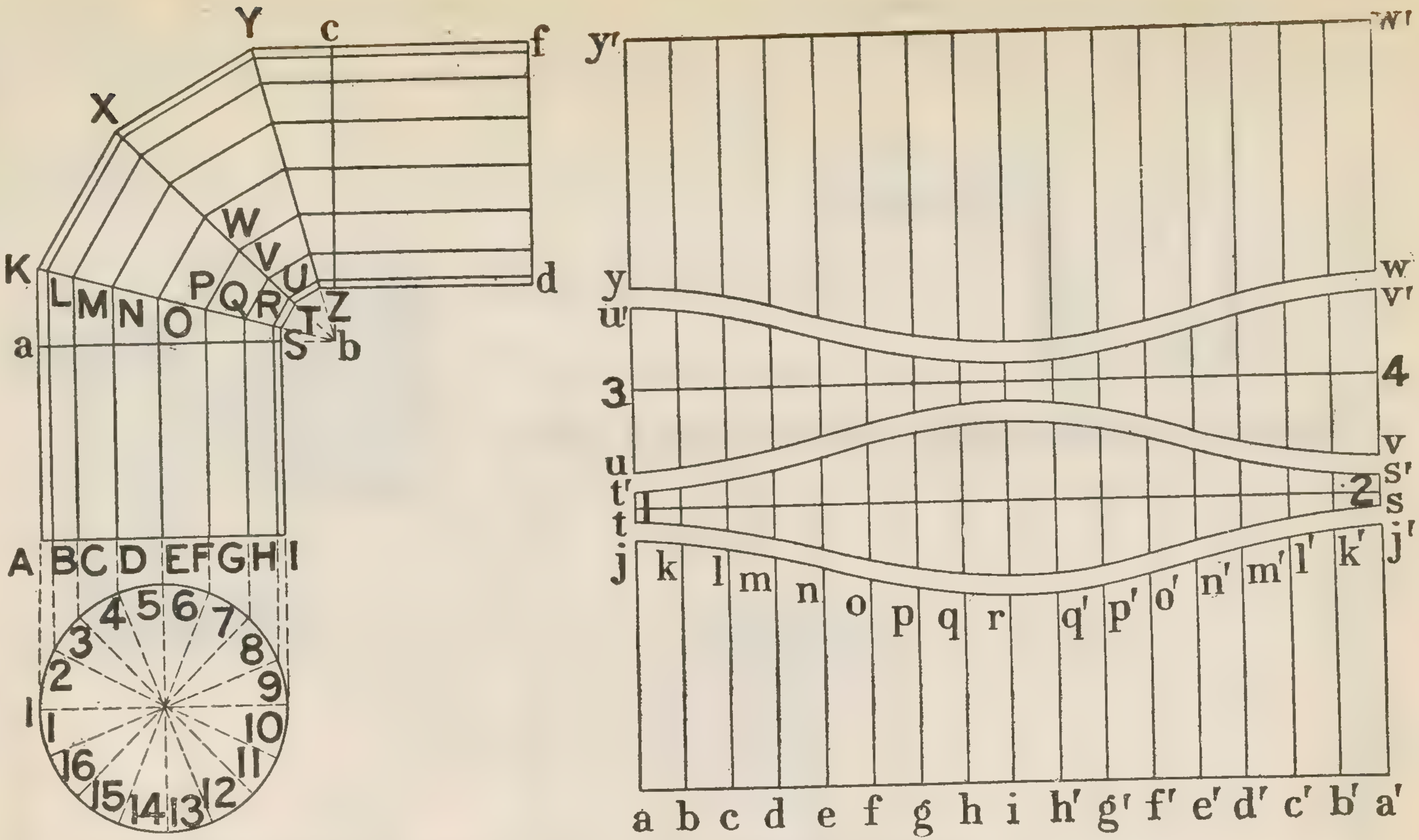


FIGS. 9,521 to 9,523.—*Problem 11.* Three piece elbow and development of its patterns.

The pattern does not show which laps should be provided for the joint. For method of making this provision see Problem 8.

Problem 11.—Patterns for a three-piece elbow. Figs. 9,521 to 9,523.

The general shape of the elbow is shown in the elevation. The imaginary cylinder from which the three parts of the desired elbow are to be had, will be equal to the combined lengths CD, IB, and KL, in elevation. This combined length is shown as EN, in the development wherein EF, is equal to DC;



FIGS. 9,524 to 9,526.—***Problem 12.*** Four piece elbow and development of its patterns.

FM, equal to BI; MN, equal to KL. The development of the imaginary cylinder is shown as the rectangle ENOH, EH being equal to the length of the circumference of the pipe shown in plan.

The development of the pattern is by elementary lines through points 0, 1′, 2′, 3′, etc., parallel to

EN. and spaced equal to the arc distance, between similar points 0,1,2,3, etc., in plan.

By projecting points 1,2,3,in plan up to miter line BC, in elevation, thence, over to pattern, the intersections with corresponding elementary lines 0,1′, 2′,3′, etc., will give points defining the curve FG.

To obtain the curve MP, draw the center line XX′ so as to bisect the distances MF and PG. Then, set off upon each of the elementary lines 0,1′, 2′,3′, etc., above XX′, the amount which the curve FG, deviates from XX′, thus obtaining similar points which define curve MP.

Problem 12.—Patterns for a four piece elbow. Figs. 9,524 to 9,526.

In the elevation, the four pieces forming the elbow are AKSI, KXTS, XYZT, and Y*fd*Z. Of these four parts, the two larger parts, AKSI and Y*fd*Z, are equal. The same is true of the two remaining smaller parts KXTS and XYZT.

To lay out these parts in the elevation a right angle *abc*, is drawn, the sides of which intersect at right angles, the two largest branches of the joint. It is evident that the point *b*, must be equidistant from both pipes.

The right angle *abc*, is divided first into three equal parts and then each one of these parts is divided in turn into two equal parts; the right angle is thus divided into six equal parts, of which K*ba*, is one part, K*b*X, equals two parts, X*b*Y equals two parts and Y*bc* one part. It will be noticed that this construction does not depend on the diameter of the pipe.

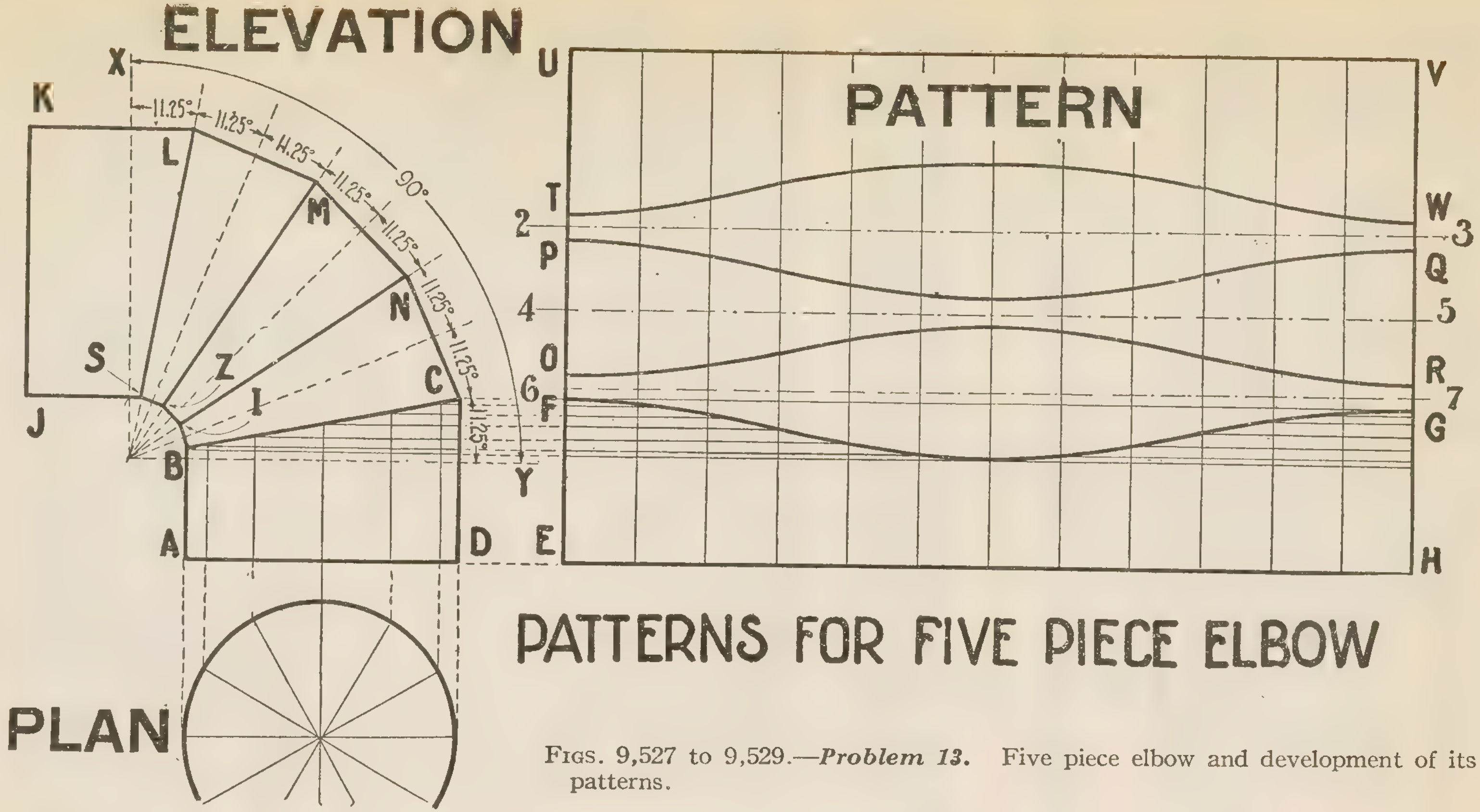
The problem of developing the four part elbow resolves itself into developing two only of its parts, one large branch and one smaller part of the elbow, the remaining parts being correspondingly equal to these.

The circumference of the pipe, as seen in plan, is divided into sixteen equal parts by the points 1,2,3,4,5, etc.

Through these points are drawn lines parallel to the center line of the pipe which is to be developed.

In the development, the vertical branch of the elbow, (AKSI, of the elevation), will be taken up for the purpose. The parallels upon the surface of this branch are AK, BL, CM, DN, EO, FP, GQ, HR, and IS. Through the points K,L,M,N,O,P,Q,R, and S, draw parallels for the part KXTS, which will be next developed; some of these parallels are ST, RU, QV, PW.

To develop the vertical branch of the four piece elbow set off, upon a



FIGS. 9,527 to 9,529.—***Problem 13.*** Five piece elbow and development of its patterns.

straight line *aa'*, sixteen equal parts, which altogether are equal to the circumference of the cylinder, which is to be developed.

Let the division points *a,b,c,d,e,f*, etc. correspond to the division points, 1,2,3,4, etc., upon the circle in plan. Through the points, *a,b,c,d,e*, etc., draw vertical lines equal to the parallel lines drawn upon the surface of the vertical branch of the joint; thus *aj*, is made equal to AK, *bk*, equal to BL; *cl*, equal to CM and so on until *ri* is made equal to SI.

The part laid out so far is *ajklmnopqri*. This is one-half of the development; the other half, *irj'a'* being exactly the same as the first one, may be laid out in the same way.

The part *tt'ss'* is the development of the small part of the elbow. It is evident that its length, *ts*, must be equal to the circumference of the pipe in the elbow. The lines in the pattern, *tt'ss'* drawn at right angles to the center line of it, and bisected by it, are made equal to the parallel lines, ST, RU, QV, PW, etc., drawn upon the surface of the part, KXTS, in the development.

It is plain that the part, *uu'vv'* is equal to the part *tt'ss'*, with the difference that the small parallels in it are laid out above the large parallels in the other part; in the same manner, the part *yy'ww'* is equal to the part *aja'j'*.

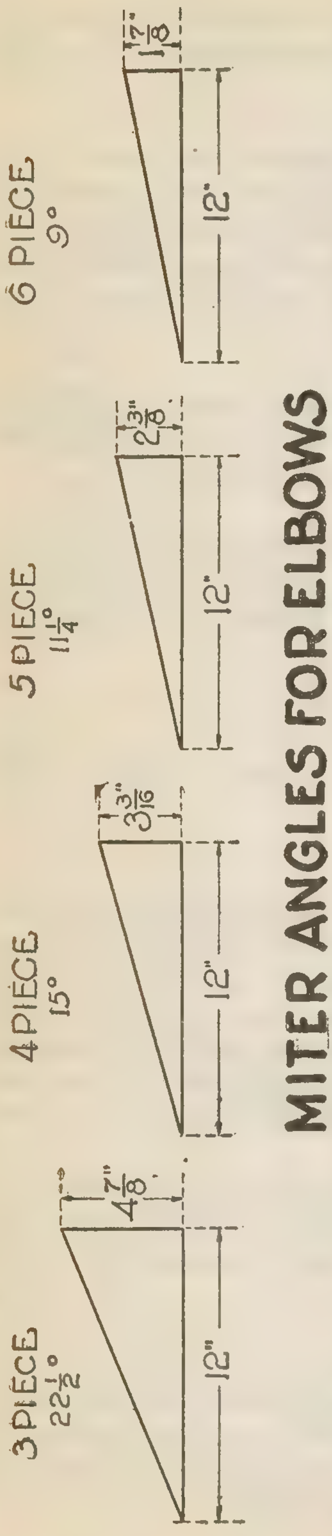
Laying out the pattern in this manner makes it possible to cut out the complete elbow from the square piece of metal, *ay'w'a'*. The spaces between the patterns are left for laps, which are necessary for joining all parts.

Problem 13.—Patterns for a five-piece elbow. Figs 9,527 to 9,529.

The five parts of the elbow may be thought of as so many parts of one long pipe, cut to the miter angle at proper distances. The length of that cylinder, this time, will be made up of the sum of the alternately consecutive outlines of the five parts of the elevation of the required elbow. Thus, in the development of the whole cylinder shown at EUVH, the vertical edge EU, is equal to the combined lengths of DC,BI,MN,ZS and KL, laid off on the development as the lengths EF,FO,OP,PT and TU.

Along the horizontal edge of the development, on EH, lay off all the equal parts into which the circumference of the elbow pipe is divided and, from the points of division on the edge EH, draw vertical elementary lines across the development.

From the division points on the circumference, projecting lines are drawn upward to the miter line BC, cutting it in a number of points from which, in turn, horizontal projecting lines are drawn meeting the vertical elementary lines on the development in points forming the curve FG. The miter line, as is seen in the elevation, has an angle of 11¼°.



Figs. 9,530 to 9,533.—*Problem 14.* Proportions of right triangles for obtaining miter angles for round pipe elbows.

The curve OR, is plotted so as to be an exact counterpart of the first curve, at the other side of the center line 6,7, which bisects OF, and RG; that is, curve OR, is the curve that would be obtained by revolving curve FG, 180° on 67, as an axis.

Having obtained the second curve OR, a second center line 45, is drawn bisecting OP and RQ, and, above this center line, the curve PQ, is plotted so as to deviate from the center line, along each vertical elementary line exactly as much as the curve OR deviates from the center line.

In a like manner, with the aid of the third center line, 23, the curve TW, is laid out opposite and equal to the curve PQ, the center line 23, bisects PT and QW. For simplicity in explaining the development no laps are provided for joints. The method of making this provision is explained in Problem 8.

Problem 14.—Miter angles for round pipe elbows. Figs. 9,530 to 9,533.

In all elbows, the miter upon the end piece depends upon the number of pieces of which the elbow is to be made up.

For a 2 piece elbow, the miter angle is 45°.
" " 3 " " " " " " 22½°.
" " 4 " " " " " " 15°.
" " 5 " " " " " " 11¼°.
" " 6 " " " " " " 9°.

The angles can be traced with the aid of a protractor. However, sufficiently accurate angles may be laid out for the different

miters by the handy method of right triangles shown in figs. 9,530 to 9,533. The miter angle for a 3 piece elbow may be obtained by con-

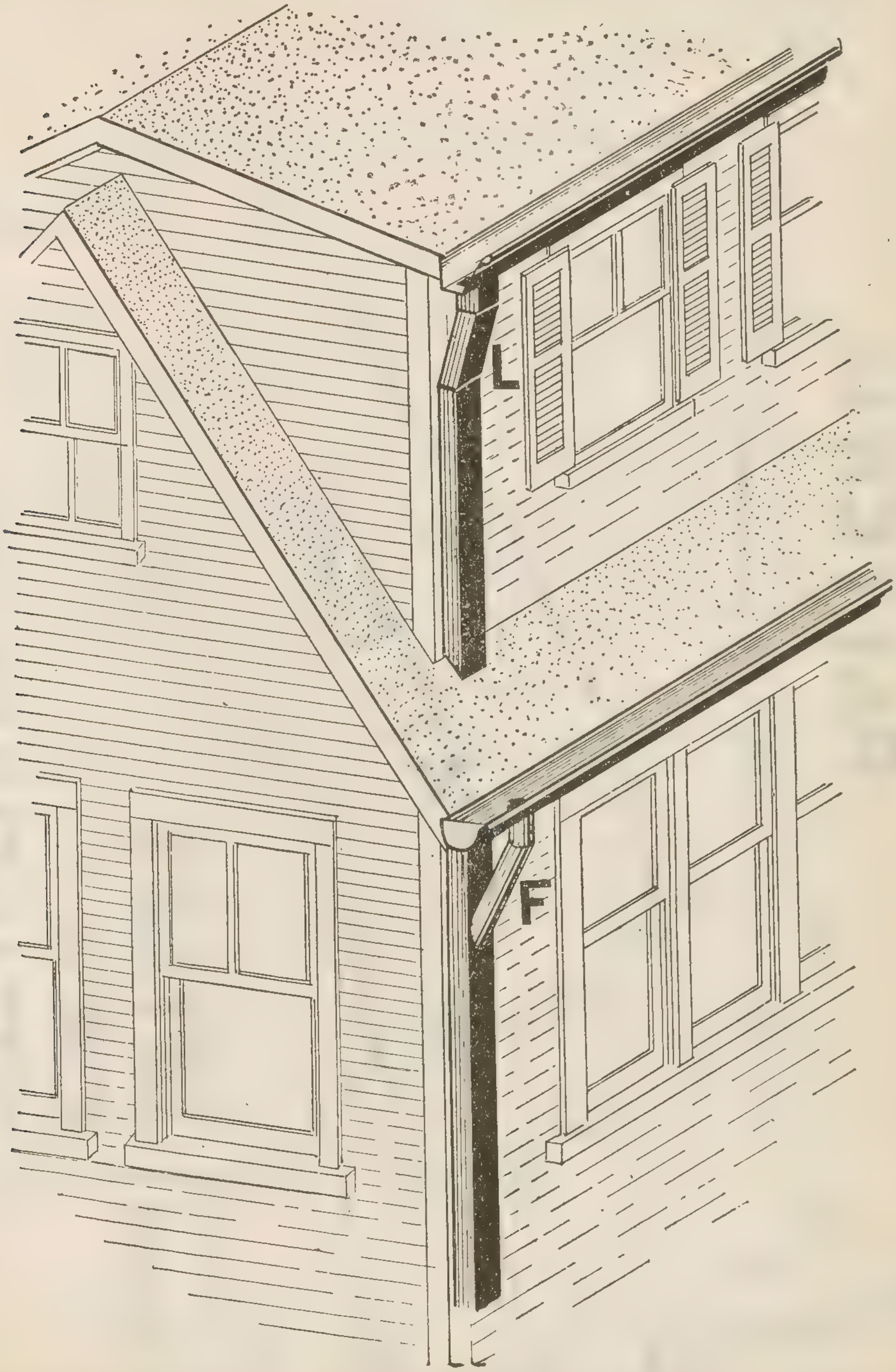


FIG. 9,534.—Leader construction on house showing general appearance of parts for problems 11 and 12. **L**, offset on rectangular leader (problem 11); **F**, branch from leader (problem 12).

FIGS. 9,535 to 9,538.—***Problem 15.*** Offset on a rectangular leader and development of its patterns.

structing a triangle, one leg of which is 12 ins. long, the other leg 4⅞ ins. long. The hypotenuse of this triangle gives the desired miter.

The proportions for the various other miters are given in figs. 9,530 to 9,533. The miter for any elbow not given in the illustrations may be found as follows:

Rule.—*Divide by* 90 *the number of pieces in the elbow less one, multiplied by two.*

Thus for a three piece elbow, $90 \div (3 - 1)\,2 = 22\frac{1}{2}°$.

Problem 15.—Patterns for an offset on a rectangular pipe. Figs. 9,535 to 9,538.

The general appearance of this offset is shown at L, in fig. 9,534.

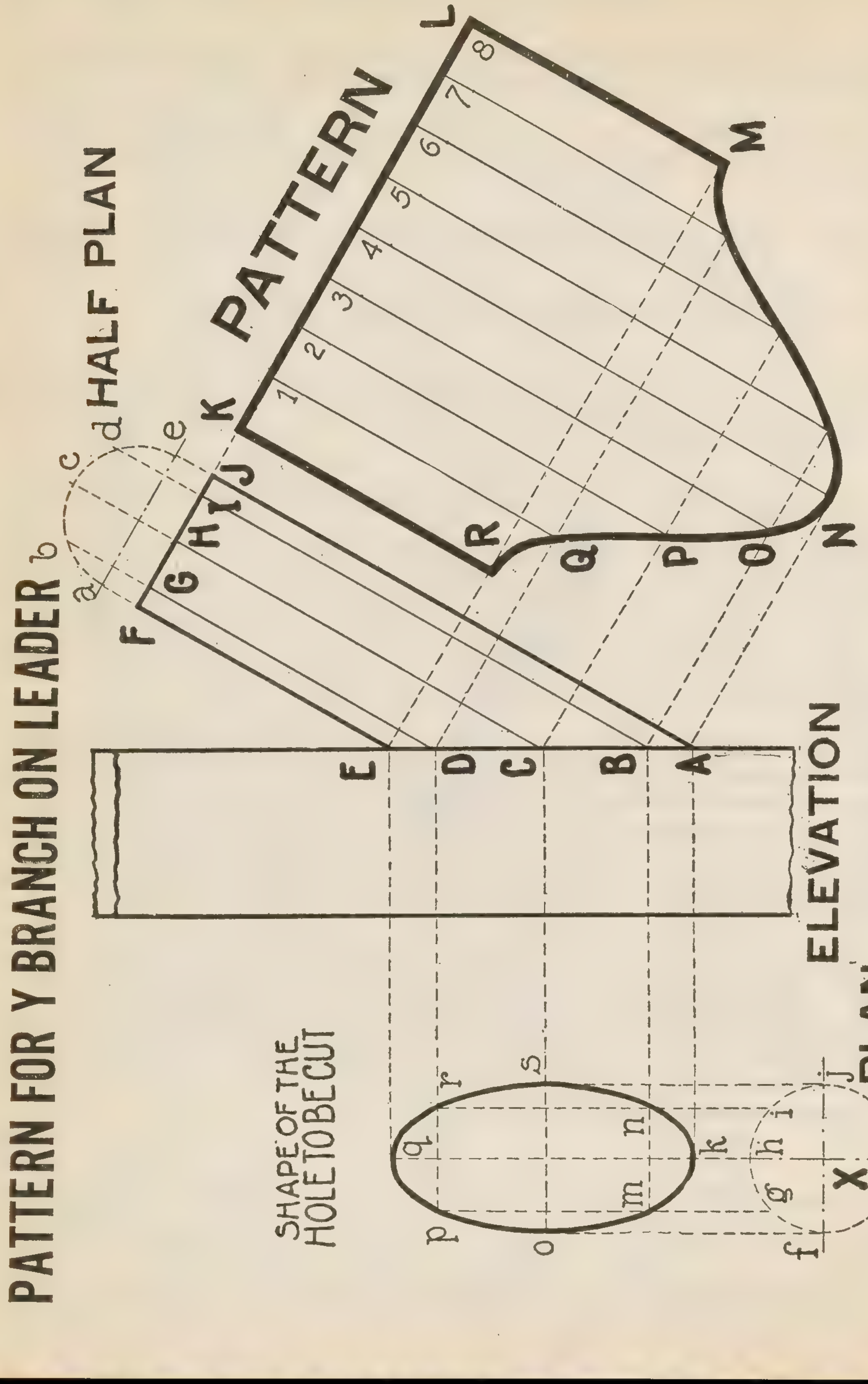
In making an offset on any pipe it is necessary to keep in mind that all parts of it should offer the same area for the even flow of the water within the pipe. Hence, in the elevation, the cross section of the oblique part of the pipe, FGJK, has the same width as the vertical part. To obtain this result, the joint FK, must be drawn so as to bisect the angle EFG, and likewise, the joint GJ, must bisect the angle KJI.

For the patterns of the offset, the four sides of the plan ABCD, are laid off, consecutively, upon the line MNOPQ, and in the points of measurement, elementary lines are drawn at right angles to the line MQ. Upon these lines are projected the vertical measurements of the part to be developed. Thus ML, is equal to GH, and SN, is equal to JI. The drawing of the pattern LMQR, plainly shows its derivation from the upright part GHIJ, by means of the projection lines.

For the development of the oblique part of the square pipe FGJK, project lines from points F,G,J,K, at right angles to the length of the oblique section. These lines cutting the line UV, in the points V,W,T,U, give starting points for horizontal projectors that determine the lengths of of the different portions of the development WUYZ. Joint laps should be added to the pattern, thus obtained.

Problem 16.—Patterns for round branch from rectangular leader. Figs. 9,539 to 9,543.

The general appearance of this branch is shown at F, in fig. 9,534.



FIGS. 9,539 to 9,543.—***Problem 16.*** Round branch from rectangular leader and development of its pattern.

In the elevation the round branch AEFJ, cuts the rectangular leader along a curved line that is symmetrical lengthwise and crosswise; the curve is an ellipse.

In the half plan of branch the circumference of the branch is divided into a number of equal arcs (half of the circumference being shown with the dividing points *a*,*b*,*c*, etc.).

Through *b*,*c*, and *d*, project the elementary lines GD, HC, and IB. The elements through the point of division intersect the square pipe in the points A,B,C, etc.

Now, for the pattern of the round pipe, make the line KL, a continuation of the line FJ, and equal to the combined length of the divisions on the circumference of the oblique pipe.

Lay off points 1,2,3, etc., on KL, spaced equal to arc distances *ab*, *bc*, *cd*, etc., in half plan, through points 1,2,3, etc., draw elements perpendicular to KL, and project over points A,B,C, etc., parallel to KL, and intersecting the element at R,Q,P, etc. Through these points describe the curve RNM, and join points K,R and L M, thus completing the pattern.

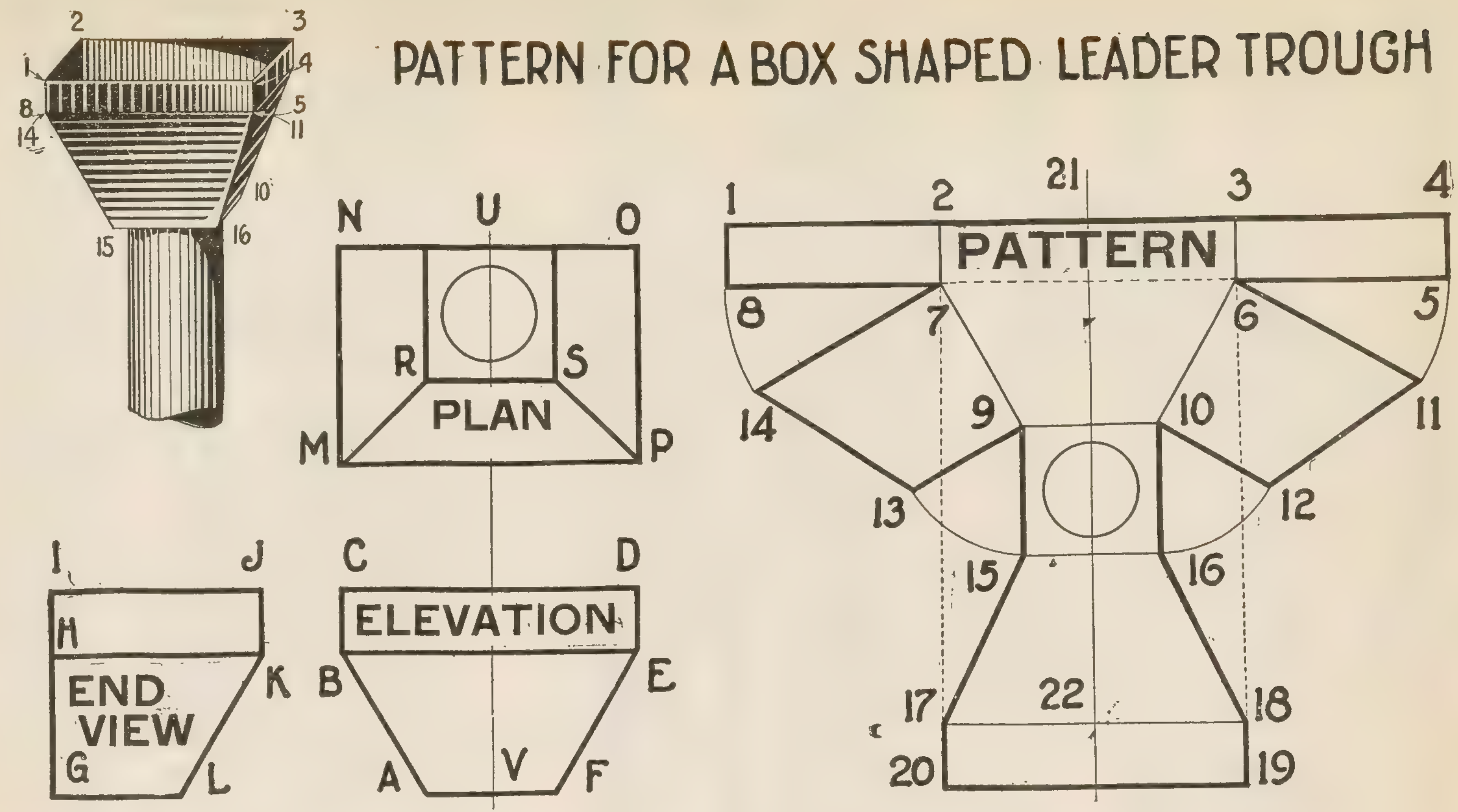
Laps for joints must be added.

The opening to be cut in the rectangular leader is an ellipse. It is obtained by projecting points A,B,C, etc., from elevation and points *f*,*g*,*h*, etc., from plan X. The intersections give points *k*,*m*,*o*, etc., which define the ellipse.

NOTE.—***Leaders.*** For quickly computing the size to be allowed for a leader, 1,800 sq. ft. of roof area for a 3 in. round leader or its equivalent in area for a square shaped leader. From 1,800 to 2,250 sq. ft. for a 3½ in. round leader or its equivalent in square leader. From 2,250 to 3,000 sq. ft. for a 4 in. round leader or its equivalent in square leader. From 3,000 to 5,000 sq. ft. for a 5 in. round leader or its equivalent in square leader. From 5,000 to 7,000 sq. ft. for a 6 in. round leader or its equivalent in square leader. Horizontal leaders should be larger and should be set with as much inclination as possible from the horizontal.

NOTE.—Judgment should tell what size leader to use when the roof area passes from one size or factor to another. For it is more economical to use, say, a 4 in. leader for 3,000 sq. ft. of roof area; but, a 5 in. leader would give a greater factor of safety in case of an unusual rainfall.

NOTE.—It is not considered good practice to use leaders less than 3 ins. in diameter because of the danger of stoppage or freezing. 2 in. leaders, however, are often used for small porch roofs or the gutters on turret skylights. In corrugated leader, the corrugations are not figured but the smallest diameter of the pipe is called the size of the leader.



FIGS. 9,544 to 9,548.—*Problem 17.* Box shaped leader trough and development of its patterns.

Problem 17.—Pattern for a box shaped leader trough. Figs. 9,544 to 9,548.

Draw, plan, elevation and end view of the trough full size. Note that the plan and elevation is divided into two halves by a center line VU.

In the development, draw first center line 21, 22. Since the trough consists of an upright part BCDE, surmounting the tapering part ABEF, the pattern will have two corresponding portions. The rectangle 8145, provides the pattern for the two end parts 1827, and 6345, as well as for the rear part 7236, of the right band. The front part of the latter is attached at the bottom of the pattern. It is marked 20,17,18,19 and is exactly equal to 7236. Note that the center line 22,21, passes through the middle of the upper band 8145, as well as through the middle of the part 20,17,18,19.

To lay out the pattern for the tapering trough, make 976,10, exactly equal to the projection in a vertical plane of ABEF, the tapering part of the front view.

Since the elevation does not show the true length of this tapering part but its projection in a vertical plane, 976,10, is made equal to ABEF.

To the lower edge, 9,10, then, attach the rectangle 15,9,10,16, which is equal to the bottom RUS, of the trough. At the points 7 and 9, erect the lines 7,14, and 9,13, at right angles to the line 9,7. Similarly, at the points 10 and 6, erect the lines 10,12 and 6,11, at right angles to the line 10,6. Then the irregular figure 13,14, 79, forms the left side of the tapering part, while the figure 12,10,6,11, forms the right side of the tapering trough.

Draw lines 2,20 and 3,19, parallel to the center line 21,22, and with a radius equal to 12, 11, from center 16, describe an arc cutting the line 3,19, at the point 18, and, with the same radius, from center 15, describe an arc cutting the line 2,20, at the point 17. Connect the points 17 and 18, by a straight line and obtain the front face 17,15,16,18, of the trough.

Finally, to the edge 17,18, attach the band 20,17,18,19, equal to 7236.

At the center of the square 976,10, describe a circle for the opening, whose diameter is equal to the diameter of the round leader.

Add to the pattern proper laps for the seams.

Problem 18.—Pattern for a pan. Figs. 9,549 to 9,552.

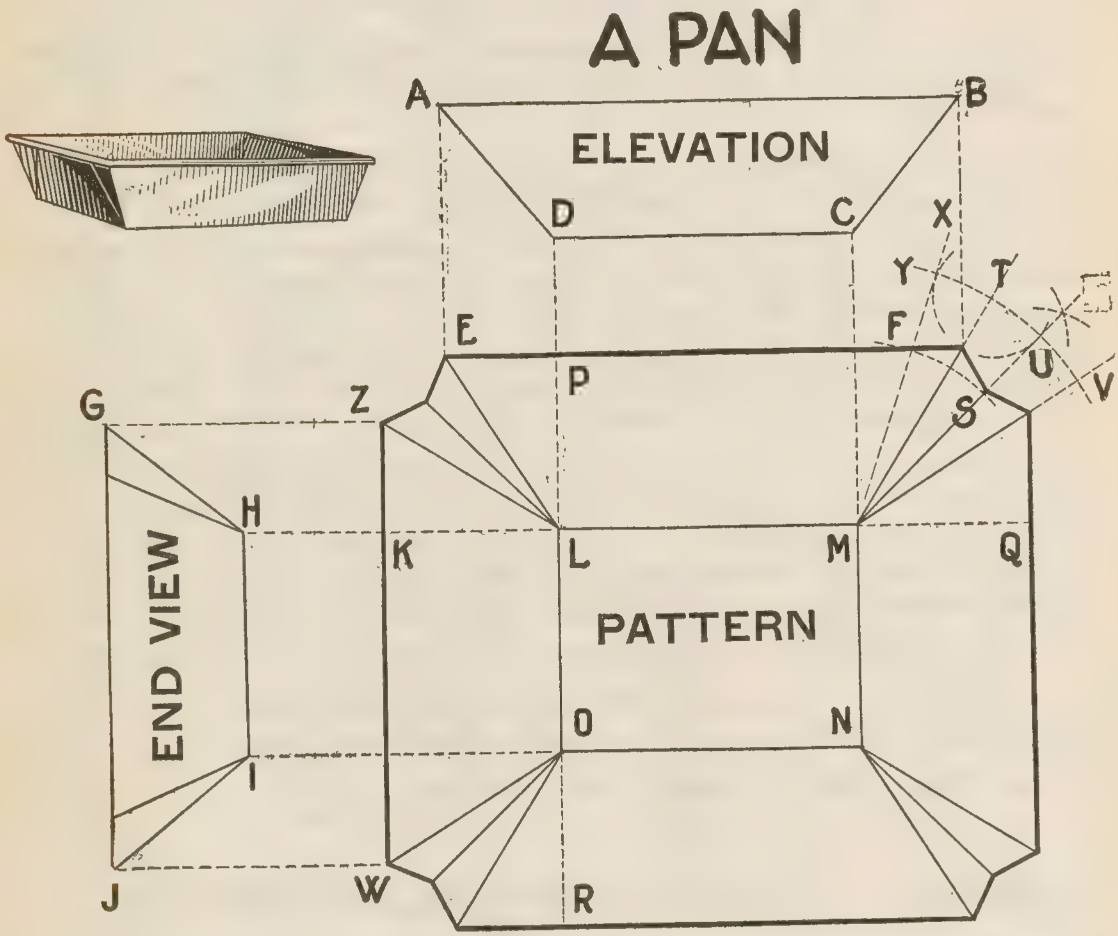
Draw elevation and end view. The flare on all sides being equal in this pan, the oblique edges in both views make the same angle with the bottom lines. Also, these oblique lines J,HG,DA and CB, are equal in length.

The pattern is to be made of one piece. Furthermore, its joints are not to be soldered but made water tight by turning some of the stock of the sides flatly upon the end walls of the pan, and this in such a manner that the folded metal should reach exactly to the wired edge.

To draw the pattern, project the corner points I,H,D and C, of the end

view and elevation so as to form, by intersection, the rectangle OLMN; this is the bottom of the pan.

Space off distance LK, LP, MQ and OR, each equal to the oblique line HG. Draw lines through these points, and project from points J,G,A,B, lines intersecting at W,Z,E, etc., giving outer edges of the pan. Connect points W,Z,E, etc., to the rectangle OLMN, which gives the four sides



FIGS. 9,549 to 9,552.—***Problem 18.*** Rectangular baking pan and development of its pattern.

of the pattern. This KL, LP, MQ and OR, is each equal to the oblique line GH.

Upon these outer edges now project the distances JG and AB, to the points W,Z,E and so on, which points, when connected to the corners of the rectangle ONML, furnish the shapes for the four side parts of the pattern.

The metal between the edges LZ, LE, etc., has to be so shaped that, upon upon being folded up on the side wall, it should reach exactly to the wired edge. The procedure for this purpose is explained in the upper right corner of the pattern. The acute angle between the oblique edges of the sides, that is the angle TMV, is bisected by the line MU. Then one half of the bisected angle is laid off alongside of it. Thus the angle UMT, is laid off at TMX.

This is done by making the arc TY, equal to the arc TU. Now, from the point F, where the edge of the added angle cuts the edge EF, an arc is drawn with the radius MF, from the point M, as center, cutting the bisecting line MU, in the point S, which determines the angular shape to which this corner, as well as all the other corners, should be cut.

For purposes of wiring it is necessary to add along the outer edges a strip sufficient partly to enclose the wire. The amount required for this purpose is equal to approximately three fourths of the circumference of the wire.

Problem 19.—Pattern for foot piece of bath tub. Figs. 9,553 to 9,558.

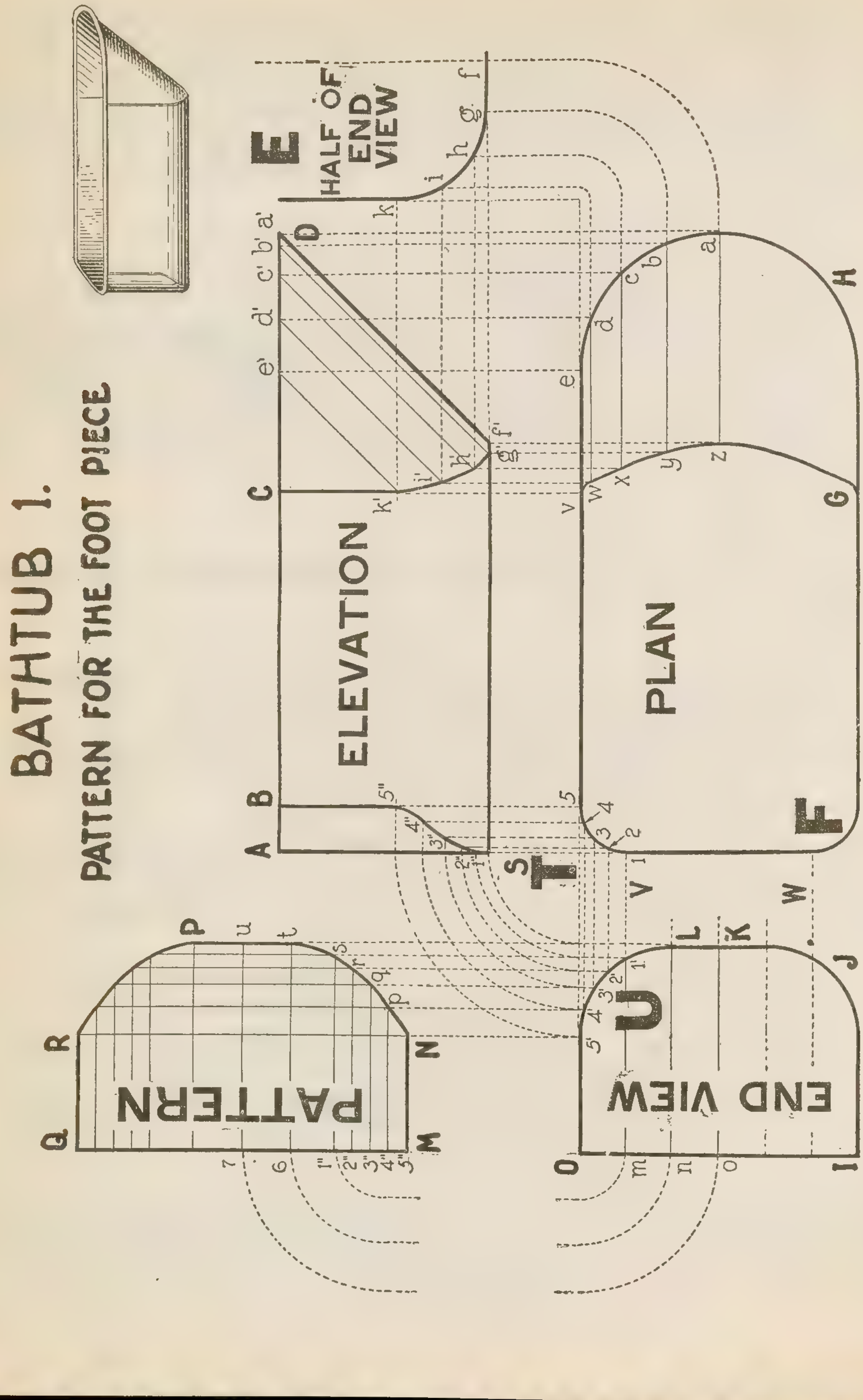
The bath tub here considered is of the type intended to be encased in wood. The foot piece is at an angle of 45° with the bottom.

The laying out of the patterns for the tub can not be accomplished without first drawing a plan, elevation and end view, including the joint edge between the body piece and the foot and head pieces.

After laying out the outside lines of the three views, with standard dimensions (or, for practice, to any convenient small scale) proceed to plot the joint edges 1″,2″,3″,4,″5″, and *g′*,*h′*,*i′*,*k′*, on the elevation, and *v*,*w*,*x*,*y*,*z*, on the plan.

Divide the corner T, in the plan, into any number of equal parts, say four parts, marked 1,2,3, etc. Project these points into the end view, to the corner U, at the points 1′,2′,3, etc., and which points in turn, project by means of arcs, to the edge SA, of the elevation and further on by a series of parallels of indefinite length toward the desired joint edge S5″. The intersection of these parallels with the projection lines 11″, 22″, 33″, etc., give points on the desired curved joint 1″,2″,3″, etc.

Now at the opposite end of the bath tub, divide the semi-circular outline into equal parts, by the points *a*,*b*,*c*, etc., from which, by projection, obtain the points *a′*,*b′*,*c′*, etc. From these points draw the elementary lines *b′g′*, *c′h′*, etc., on the line AC, of the elevation. In line with the elevation,



Figs. 9,553 to 9,558.—*Problem 19.* Foot piece of bath tub and development of its pattern.

repeat a half of the end view, at E. By means of arcs, as shown, carry the division a,b,c, etc., to the points f,g,h, etc., and project these points by means of horizontal parallels ff',gg',hh', etc., into the elevation toward the line Ck'. These parallels intersecting with the oblique lines $b'g',c'h'$, $d'i'$, etc., give points on the joint edge f',g',h', etc.

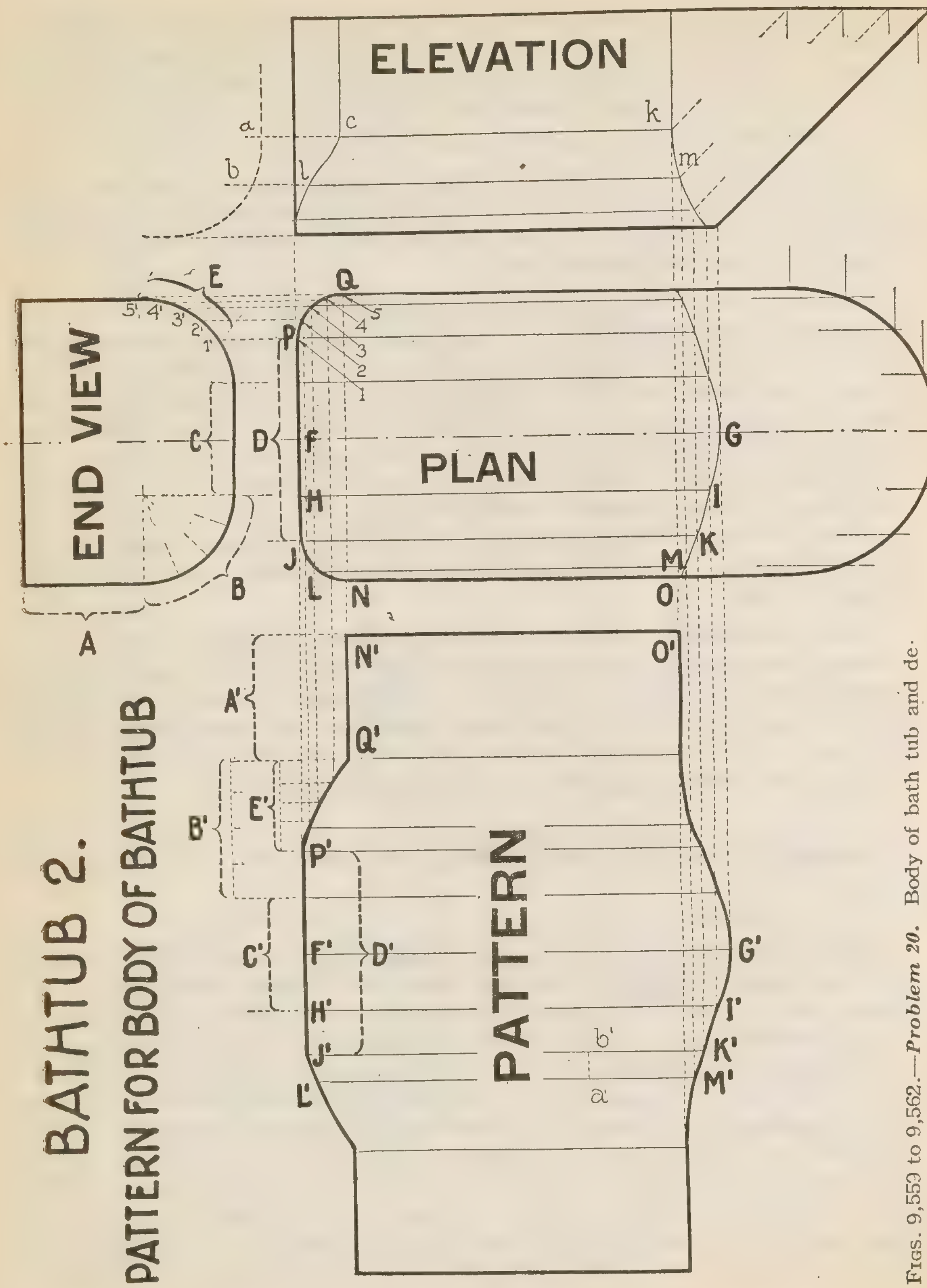
Again, the vertical projection lines drawn downward from the points f',g',h', etc. to the plan intersect the horizontal projection lines az,by,cx, etc. (in plan) in the points z,y,x, etc., which gives one half of the joint line Gv for the bottom of the bath tub.

With the three views completed, the pattern for the foot piece is plotted as follows: Extend the line O1, indefinitely, and upon its extended part from M, to Q, set off in succession, the stretched out length of the corner T (in plan), then, the distance WV, that is, the flat portion of the foot piece, and the length of the arc around the corner F. The stretched out length of the arc of the corner T (which is the same as that of corner F), is composed of the four equal divisions marked 1,2,3, etc. Thus, starting at M, measure these divisions from 5″ to 1″, thence, from 1″ to 7″, lay off one half of VW, in this manner gaining one half of the edge length of the desired pattern. The other half of that edge 7Q, is an exact counterpart of the first half.

From all divisions upon the edge MQ, draw, at right angles to it, a series of parallels toward the opposite edge of the pattern tuP, which is located upon the extension of the line KL (of the side view). Where this series of parallels is cut by the projection lines that start from 1′,2′,3′, etc., at the points s,r,q, etc., will be the curved outline of the desired pattern. It is obvious that this curve is repeated from P to R.

Problem 20.—Pattern for body of bath tub. Figs. 9,559 to 9,562.

The outline of the end view may be regarded as a cross section of the bath tub and therefore its stretched out length will furnish the length of the pattern for the body. In the end view, the cross length of the body as seen is composed of two times the length marked by A, plus two times that of the corner B, plus once the length C; that is 2A + 2B + C. On the pattern, starting at the edge N′ O′, make N′Q′ equal to the length A; next to it, starting at Q′, lay off the distance E′, equal to E; then, from the point P′, to F′, is one half of the distance D′, that is a half of the distance D. The straight edge P′J′, on the pattern, marked by D′, is equal to D, the flat portion of the foot piece. The curve P′Q′, within the distance E′, contains the sum of all the parts into which the corner E (on the side view) had been divided, that is, the distances 1′2′,2′3′,3′4′, and 4′5′. The drawing



FIGS. 9,559 to 9,562.—*Problem 20.* Body of bath tub and development of its pattern.

of the pattern plainly shows how the projection lines from the points 1,2,3,4,5 (plan view), in intersecting the short parallels drawn from the divisions upon E′, define the curve P′Q′.

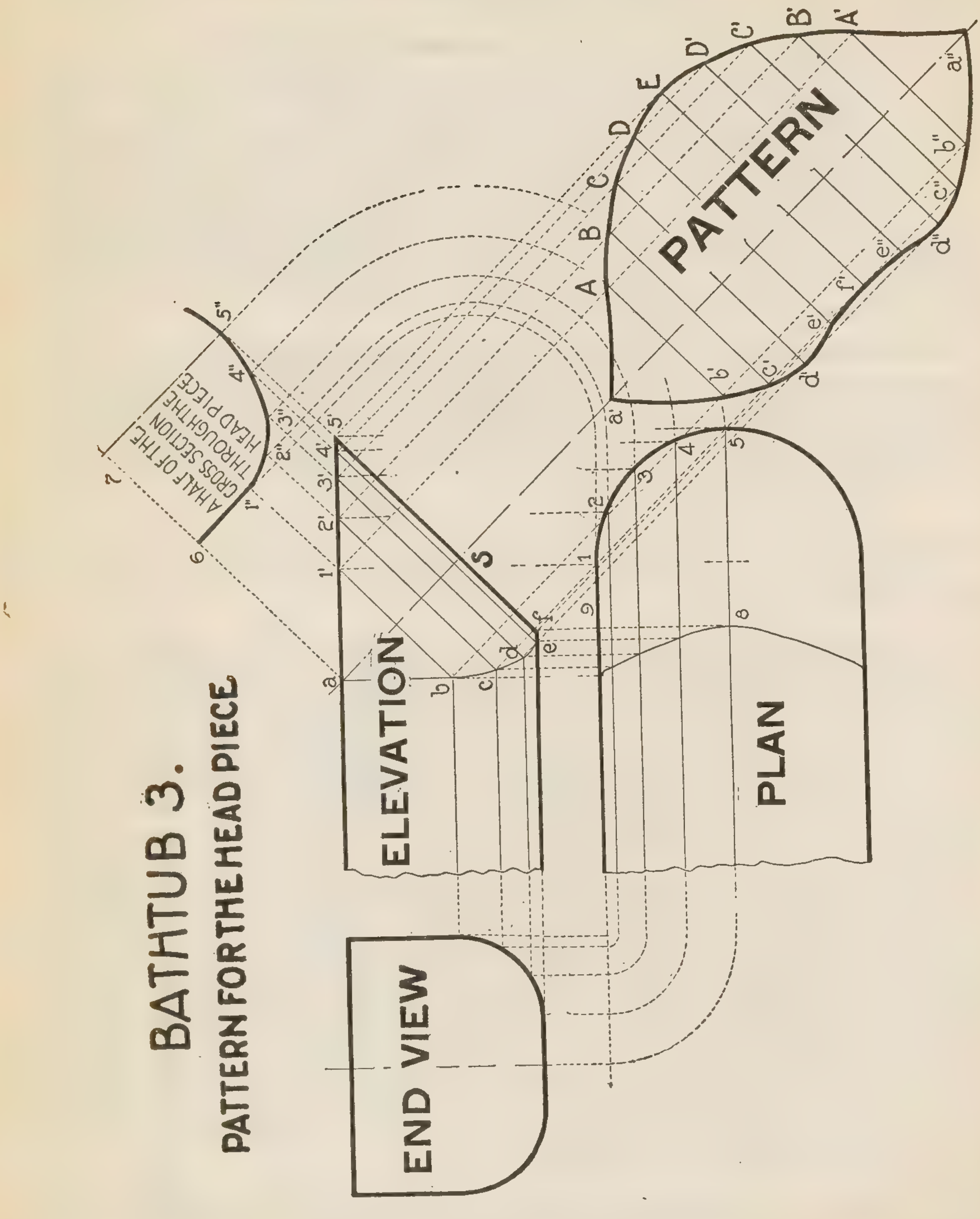
The opposite longitudinal edge of the pattern is obtained by means of projection lines from the points O,M,K,I, and G, and with the aid of parallels drawn across the pattern from the points N′,Q′,P′,F′,H′,J′,L′. The distance *a′b′*, separating the lines L′M′ and J′K′, is equal to the distance *ab* obtained from the front view, whence the lines *lm* and *ck* were projected outward, upon the arc *ab*, which arc is a reproduction of a part of the side view. Referring to the pattern, the line F′G′, is equal in length to FG (of the plan view); the line H′I′ is equal to HI; J′K′ is equal to JK and L′M′ is equal to the length of the line LM. The center line F′G′ divides the pattern into two exactly symmetrical parts.

It should be understood, that in this case, as in all problems where curve shaped patterns are to be plotted, best results are achieved when each curve is determined by a large number of points. However, in the illustrations, for the sake of simplicity, we are constrained to use only a limited number of such defining points.

Problem 21.—Pattern for head piece of bath tub. Figs. 9,563 to 9,567.

The head piece is developed by the method used for the plotting of the pattern for the slope sheet of a boiler. First, obtain a cross section through the head piece on the line S*a*, which is perpendicular to the oblique outline of the head piece. One half of this cross section is shown in the drawing. Its different points are located on the parallels that are continuations of the oblique lines 1′*b*,2′*c*,3′*d*, etc. The distance 67, is equal to 89 (in plan). The vertical distance from the point 4, to the line 85, is measured from the line 5″7, up to 4″, upon the extension of the oblique parallel *e*4′. The distance from 3, to the line 85 is laid off from the line 5″7, to the point 3″, along the next oblique parallel. The distance from 2, to the line 85, is set off from the line 5″7, to the point 2″, on the next oblique parallel,and finally, the distance from the point 1, to the line 85, is measured from the line 5″7, to the point 1″, on the next parallel. This procedure is illustrated in the drawing by means of the series of projection lines and arcs which start at the dividing points on the semi-circular edge in the plan and which lead toward the half cross section, that is to right of the front view,where they intersect the series of oblique parallels drawn from the points 1′,′2,3′, etc., thus setting off the required distances.

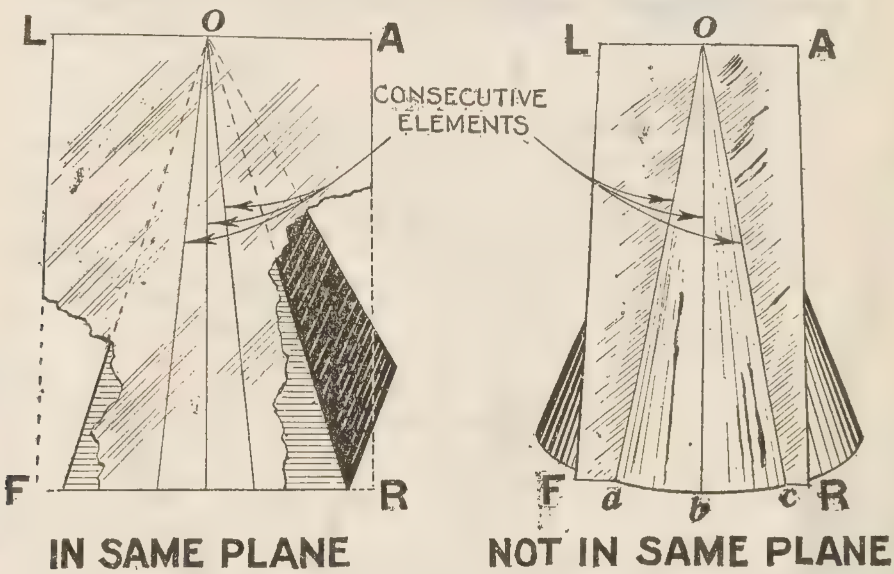
The cross section through the head piece gives the curvature of the direction of the line S*a*. When stretched out, this curvature furnishes the



Figs. 9,563 to 9,567.—*Problem 21.* Head piece for bath tub and development of its pattern.

longest measurement on the development of the head piece, namely, the line $a'a''$, on the pattern. This distance $a'a''$, is made up by putting together all the parts of the outline of the cross section, so that, starting at a', along the line $a'a''$, are laid off, one after another, the lengths 61″, 1″2″, 2″3″, 3″4″ and 4″5″, thus reaching the middle line of the pattern, the line Ef'. On the other side of Ef' the same divisions are laid off in reversed order, up to the point a''. Through these divisions on the line $a'a''$, are passed the elementary lines Ab', Bc', Cd', De' and Ef', etc.

The terminations of the elementary lines are obtained by means of the projection lines bb', cc', dd', ee' and ff', on one side of the pattern, and by the projection lines 1′A, 2′B, 3′C, 4′D and 5′E, on the other side of it.



Figs. 9,568 and 9,569.—Examples illustrating the two groups of elementary surfaces having radial elements. In the figures *oa*, *ob*, *oc*, are the radical elements and LARF, the plane.

All proper edges of the patterns for the bath tub should be provided with additional stock for necessary joint locks.

Development by Radial Lines

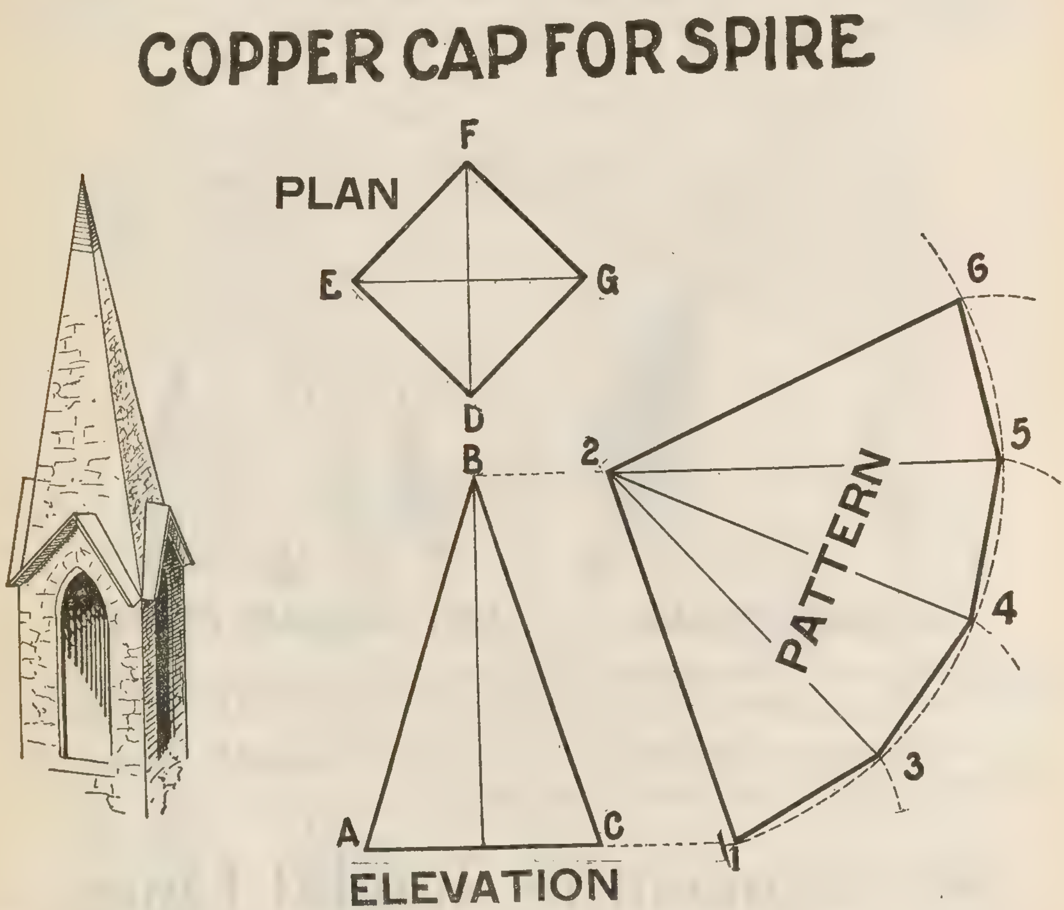
The second class of elementary surfaces are those whose elements are not parallel to each other but *radiate from a common point*. This class may be sub-divided into two groups, as

1. Surfaces having three or more consecutive elements in the same plane

2. Surfaces having no three consecutive elements in the same plane.

Surfaces such as pyramids belong to the first mentioned group, and cones to the second group, as shown in figs. 9,568 and 9,569.

The following examples are given to illustrate the method of development of such surfaces.



FIGS. 9,570 to 9,573.—***Problem 22.*** Cap for church spire and development of its pattern.

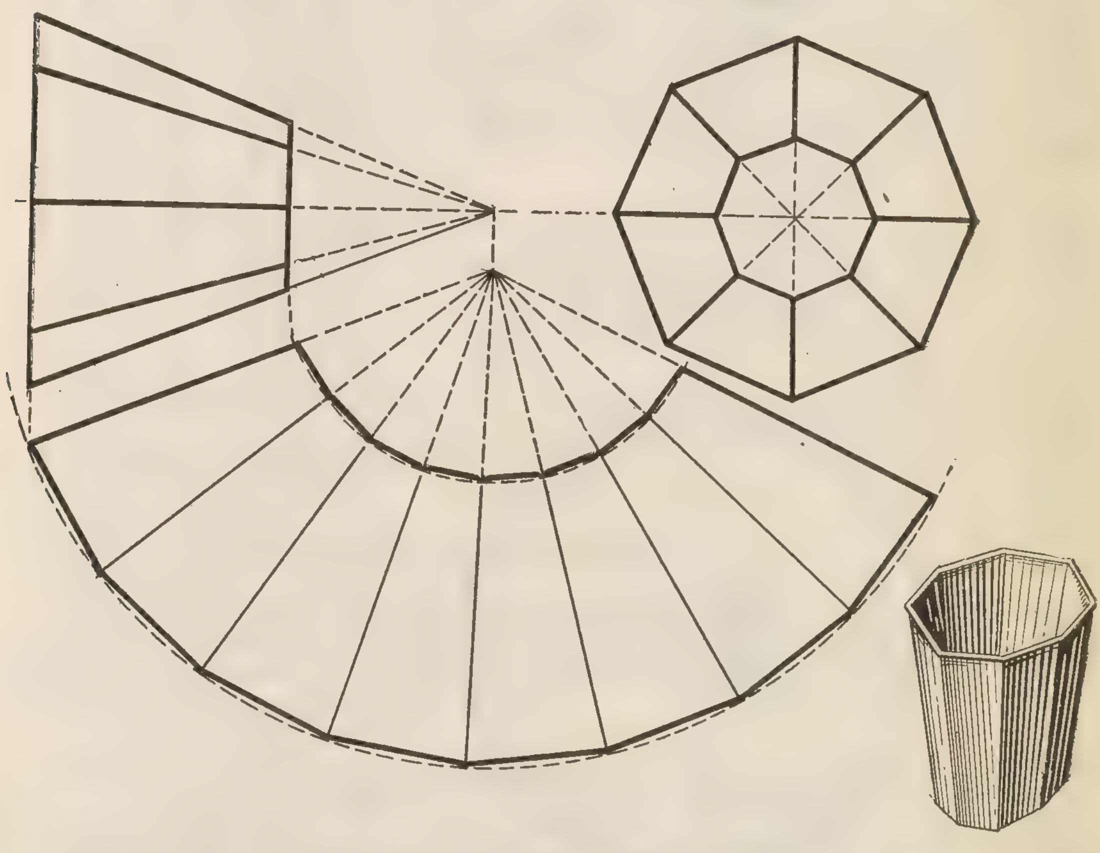
Problem 22.—Pattern for cap of church spire. Figs 9,570 to 9,573.

The required cap will have the shape of a four sided pyramid and the pattern for it is obtained by drawing the development of this pyramid.

With the oblique height of the cap CB, as radius, from the point 2, as center, describe the arc 16. Upon this arc mark off four distances, each equal to DG. The required pattern is 2 1 3 4 5 6.

All pyramids, no matter how many faces they might have, as long as all faces are equal one to another, can be developed into patterns in the manner employed in the above problem. In all cases, an arc is drawn with a radius equal to the oblique height of the pyramid, and, on this arc is laid

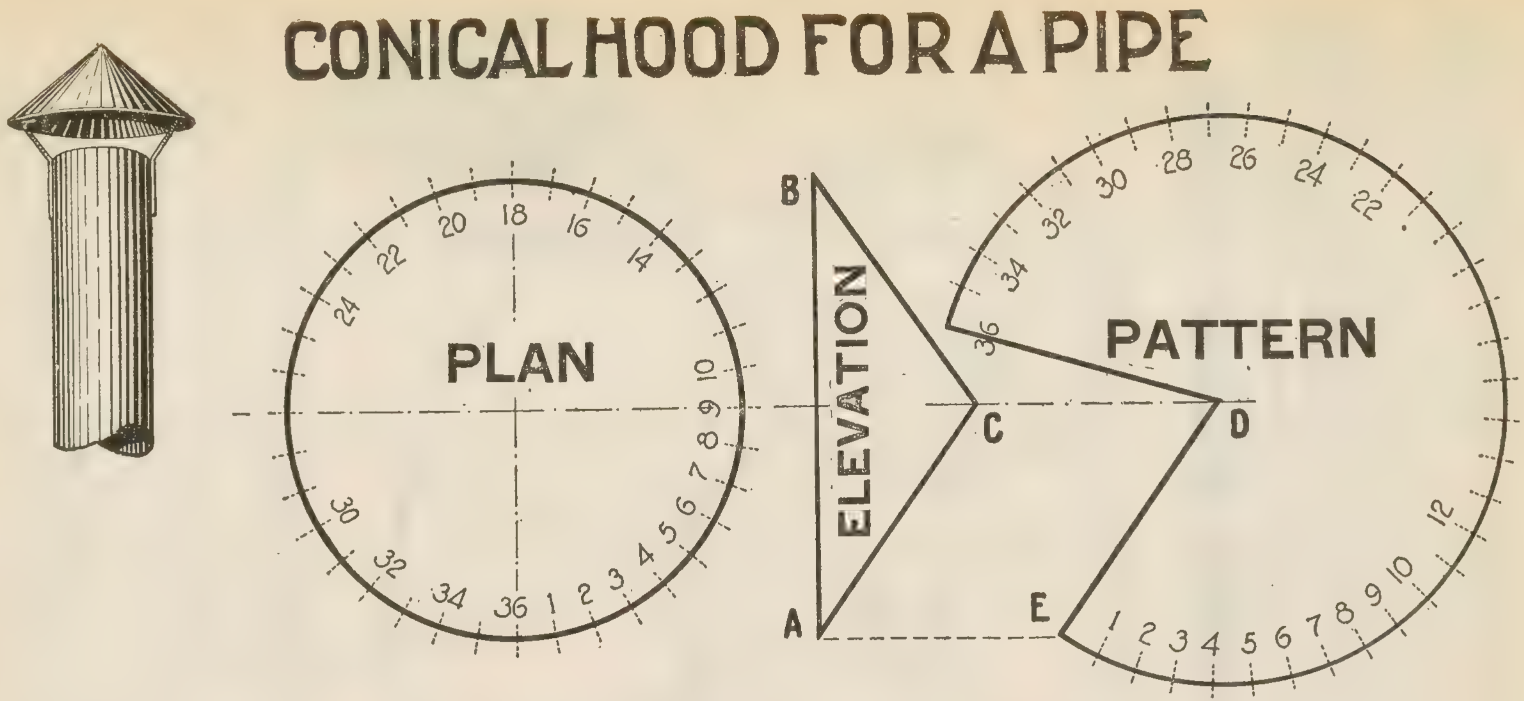
DEVELOPMENT OF A TRUNCATED OCTAGONAL PYRAMID



Figs. 9,574 to 9,577.—***Problem 23.*** Truncated octagonal pyramid and development of its pattern.

off the bottom width of one of the faces as many times as there are faces in the pyramid.

Problem 23.—Pattern for truncated octagonal pyramid. Figs. 9,574 to 9,577.



FIGS. 9,578 to 9,581.—***Problem 24.*** Conical hood on a pipe and development of its pattern.

The pattern for a truncated pyramid is readily obtainable by the method used in the last problem on the development of a pyramid. In the case of a truncated pyramid, the latter is completed by suitable auxiliary lines so as to produce a whole pyramid which, then, is seen to consist of the given truncated pyramid and a superimposed small pyramid.

Both the large and the small pyramids are developed, with arcs equal to their oblique lengths, both arcs drawn from the same center, as shown in the illustration. Thus the two developments will appear one laid upon the other, the development of the smaller pyramid occupying the corner at the center of the two arcs. In the illustration, the dotted portion is that belonging to the smaller pyramid. The remaining part of the development of the large pyramid, designated by heavy lines, is the developed pattern for the truncated pyramid.

Problem 24.—Pattern for a conical hood on a pipe. Figs. 9,578 to 9,581.

The plan of the hood is a circle. The front view (also called elevation) is a triangle whose base is equal to the diameter of the circle in the plan and whose two other sides are equal to each other. These two equal sides of the triangle give the oblique height of the cone which forms the hood.

To develop the pattern for the cone, divide the base circle into any number of equal parts, say 36. Then, from any point D, as center, with the radius DE, equal to AC, that is equal to the oblique height of the cone, describe an arc upon which, starting at the point E, set off, in succession, all the parts into which the base circle is divided, in this case, 36, equal parts, so that the full length of the circumference of the base circle will be stretched out upon the arc.

The boundaries of the required pattern are the two radial lines from the point D, and the arc that is equal, in length, to the circumference of the base circle of the cone.

Problem 25.—Pattern for smoke stack with conical hood or base. Figs. 9,582 to 9,587.

Draw elevation and plans of top and bottom.

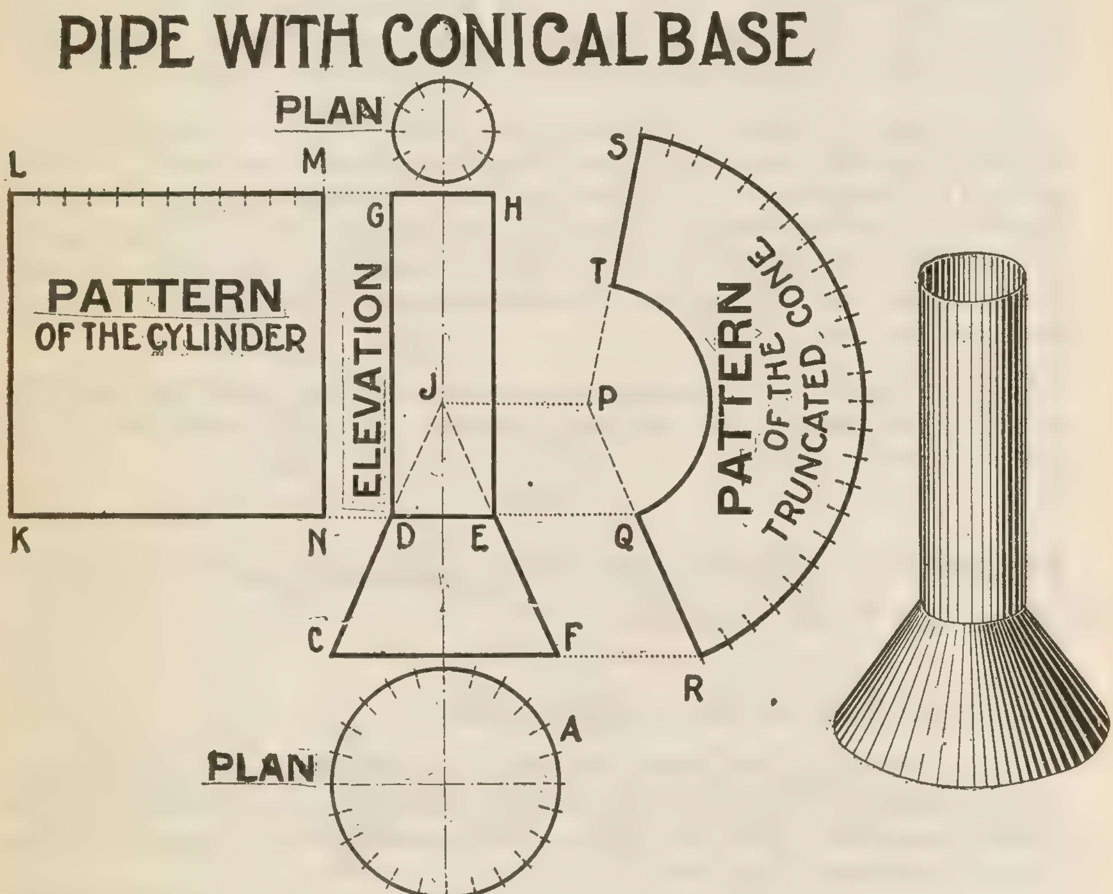
In the elevation, the base, as seen is a truncated cone, whose oblique outlines produced upward, intersect at J. This gives a large cone CJF, and a small cone DJE. Develop both of these cones from the common vertex P, and one common edge PR.

The circumference of the base circle A (in plan), divided into a number of equal parts, is stretched out upon the arc RS, whose radius PR, equals the oblique height JF of the large cone, thus the development of the entire cone CJF, is bounded by the two radial lines PR, and PS, and by the arc RS. Within the space of this development, at its corner, the space PQT, shows the development of the small cone that stands upon the truncated cone. The smaller development is made by the arc QT, which is drawn from P, as center, with the radius PQ, equal to the oblique height of the small cone.

All the space within the larger development PRS, unoccupied by the smaller development PQT, belongs to the pattern of the truncated cone.

For the laps, a circular strip should be added along the edge QT, and a straight one along TS.

To obtain the pattern for the pipe, divide its circumference into a number of parts as shown in plan. The larger the number of divisions, the



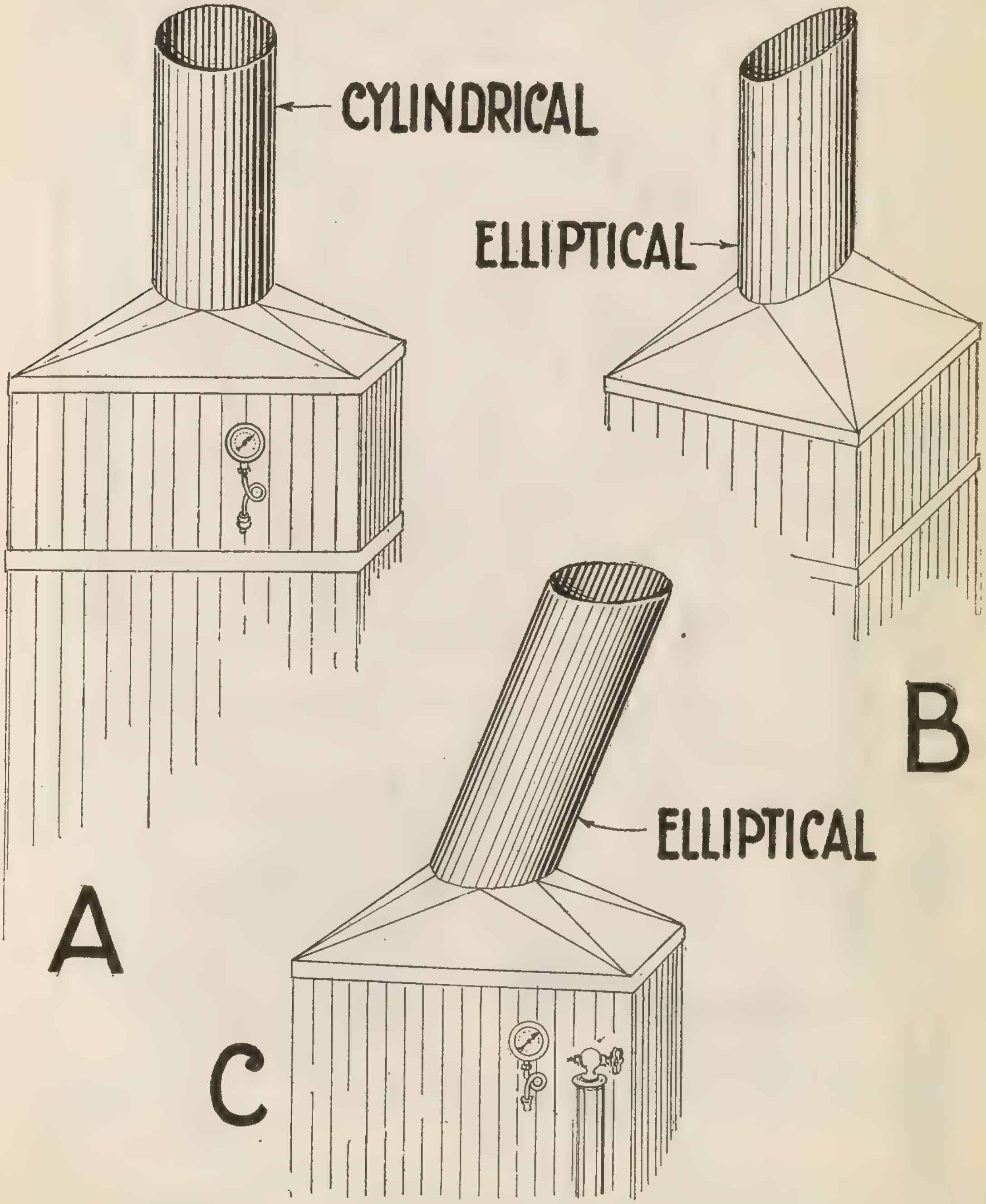
FIGS. 9,582 to 9,587.—*Problem 25.* Smoke stack with conical hood or base and development of its patterns.

more nearly true will be the resulting pattern. Then, extend the lines DE, and GH, outward toward the desired pattern. Draw the line MN, parallel to the line DG, and stretch out on ML the circumference of the pipe that is all of its divisions laid off one after another.

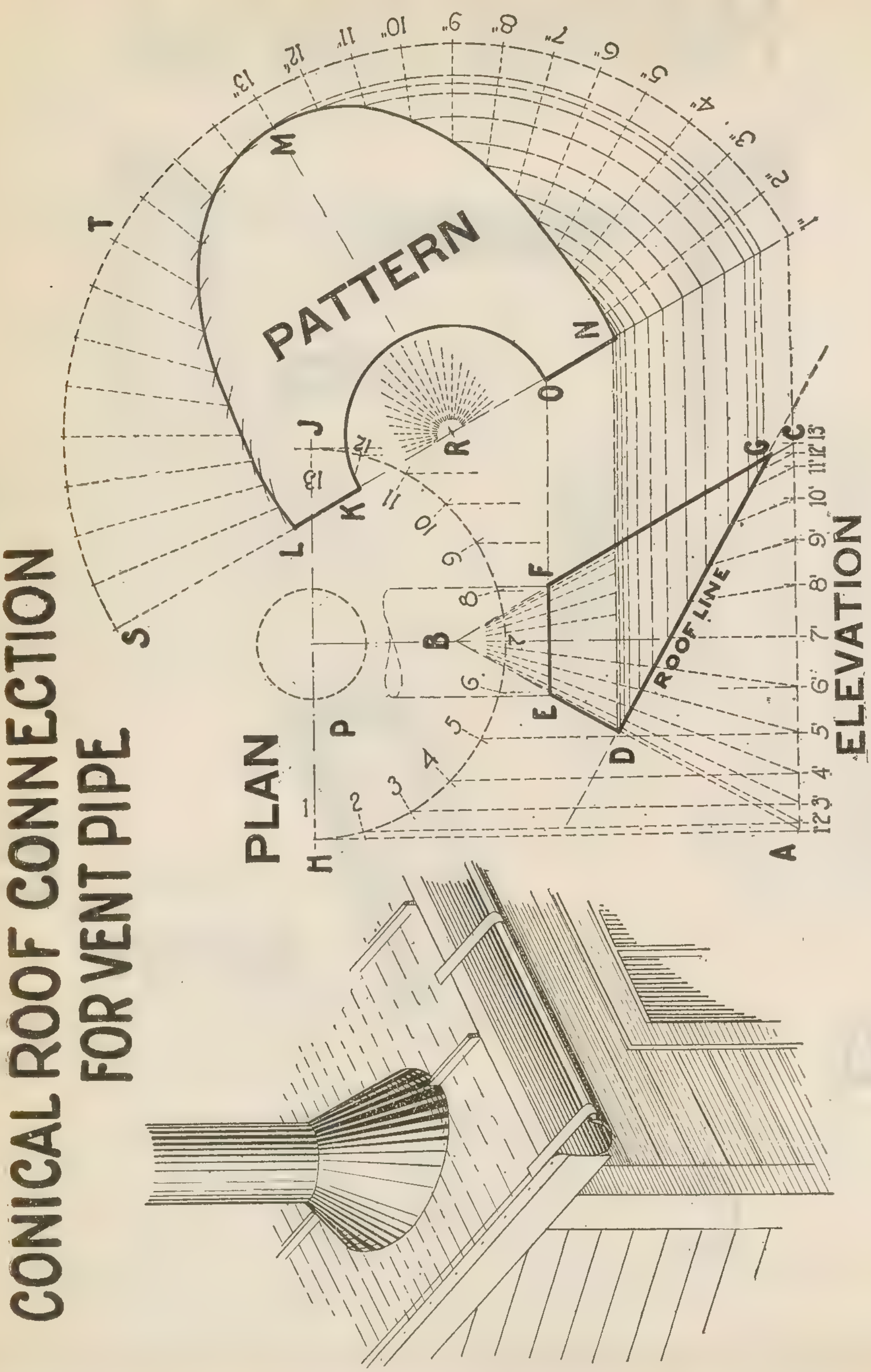
Finally draw the edge LK, parallel to MN, completing the rectangle that is the pattern of the cylinder.

Of course, for the lap, a sufficiently wide strip should be added to the

MARINE STACKS



FIGS. 9,588 to 9,590.—***Problems 26 to 28, for practice.*** **A,** cylindrical upright stack; **B,** elliptical upright stack; **C,** elliptical raked stack.



FIGS. 9,591 to 9,524.—*Problem 29.* Conical roof hood or base connecting with stack and development of its pattern.

edge KL. The width of this strip will depend upon the thickness of the metal in the pipe.

Problem 29.—Pattern for conical roof hood or base connecting with stack. Figs. 9,591 to 9,594.

The problem calls, firstly, for the development of the cone ABC, of which the roof-hood DEFG, is the central part, and, secondly, for the development of the obliquely cut lowest portion of the cone, the part ADGC, shown in the elevation.

The base circle P, of the cone, is shown in plan. This whole circle is divided into 24 equal parts, marked by the points 1,2,3, etc. From these points on the circle, vertical lines are drawn cutting the base line AC, at the points 1′,2′,3′, etc., from which points lines are drawn to the vertex B, namely the lines B1′,B2′,B3′, etc.

The development of the cone ABC, is laid out, with a radius equal to the oblique height of the cone, the distance BC, with the arc 1″TS, upon which all of the divisions of the base circle are set off, in succession, at the points 2″,3″,4″, etc., thus making the length of the arc 1″TS, equal to the whole circumference of the base circle. The development of the cone ABC is bounded by this arc and by the lines SR and RI″. Upon this development also is laid out the development of the hood DEFG. This development, is outlined with the heavy solid line ONMLK.

The roof line DG, giving the pitch of the roof, is intersected in 13 points by the lines 1′B,2′B,3′B, etc. From these points of intersection, horizontal lines are drawn to the line ON1″, giving starting points for a number of arcs upon the development. These arcs, at their meeting points with the radial lines R1″,R2″,R3″, etc., define one half of the curve.

The other half of this curve being exactly equal to the first, it can be laid out in a similar manner by means of these arcs and the radial lines in the second half of the development, the complete curve being NML.

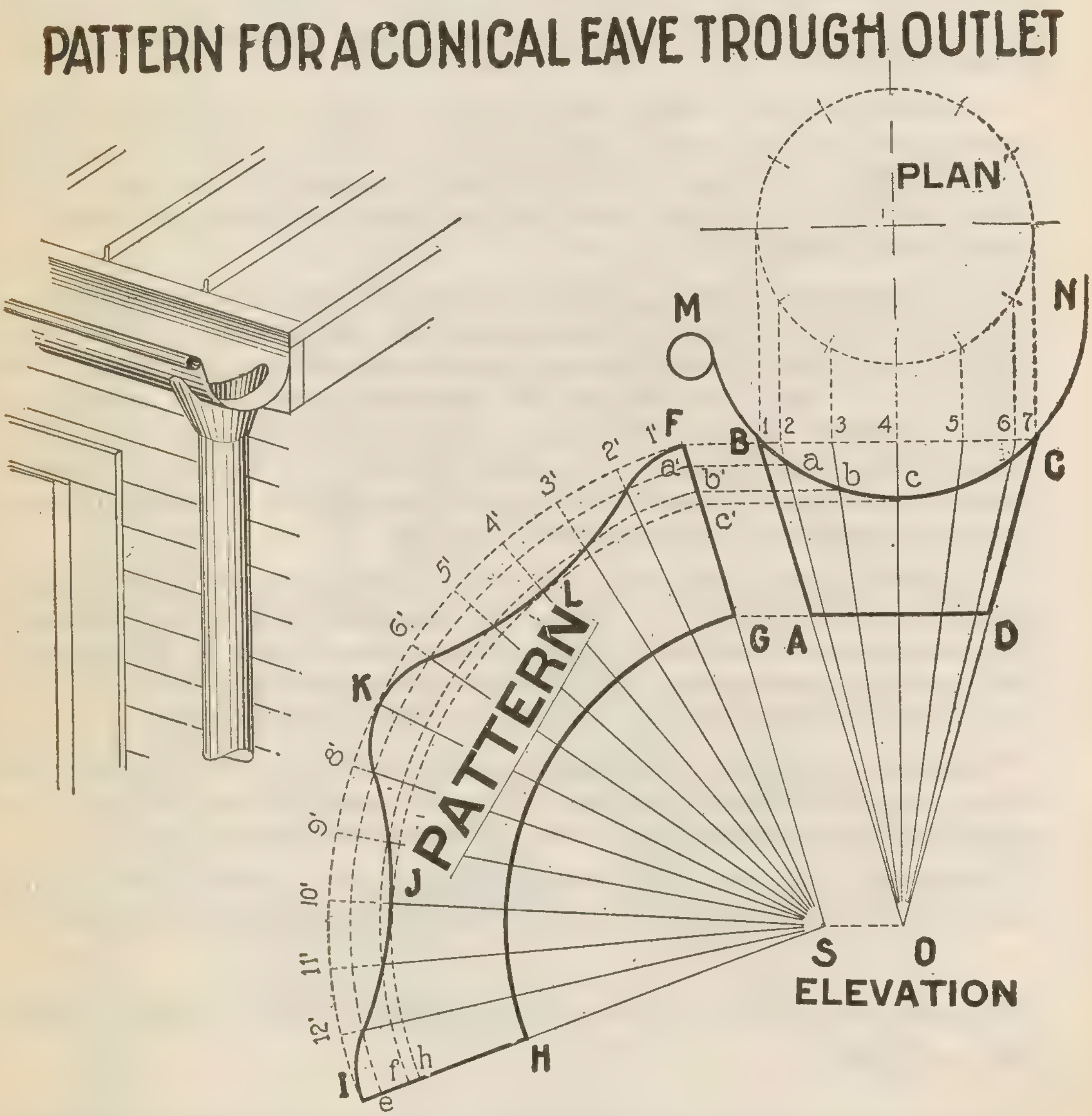
Additional stock has to be allowed for laps, along both curved outlines and along one of the straight edges of the pattern of the connection piece.

Problem 30.—Pattern for a conical eave trough outlet. Figs. 9,595 to 9,598.

It does not matter what curve be given to the gutter, oval or circular. The method explained in this case is suitable for gutters of all curvatures.

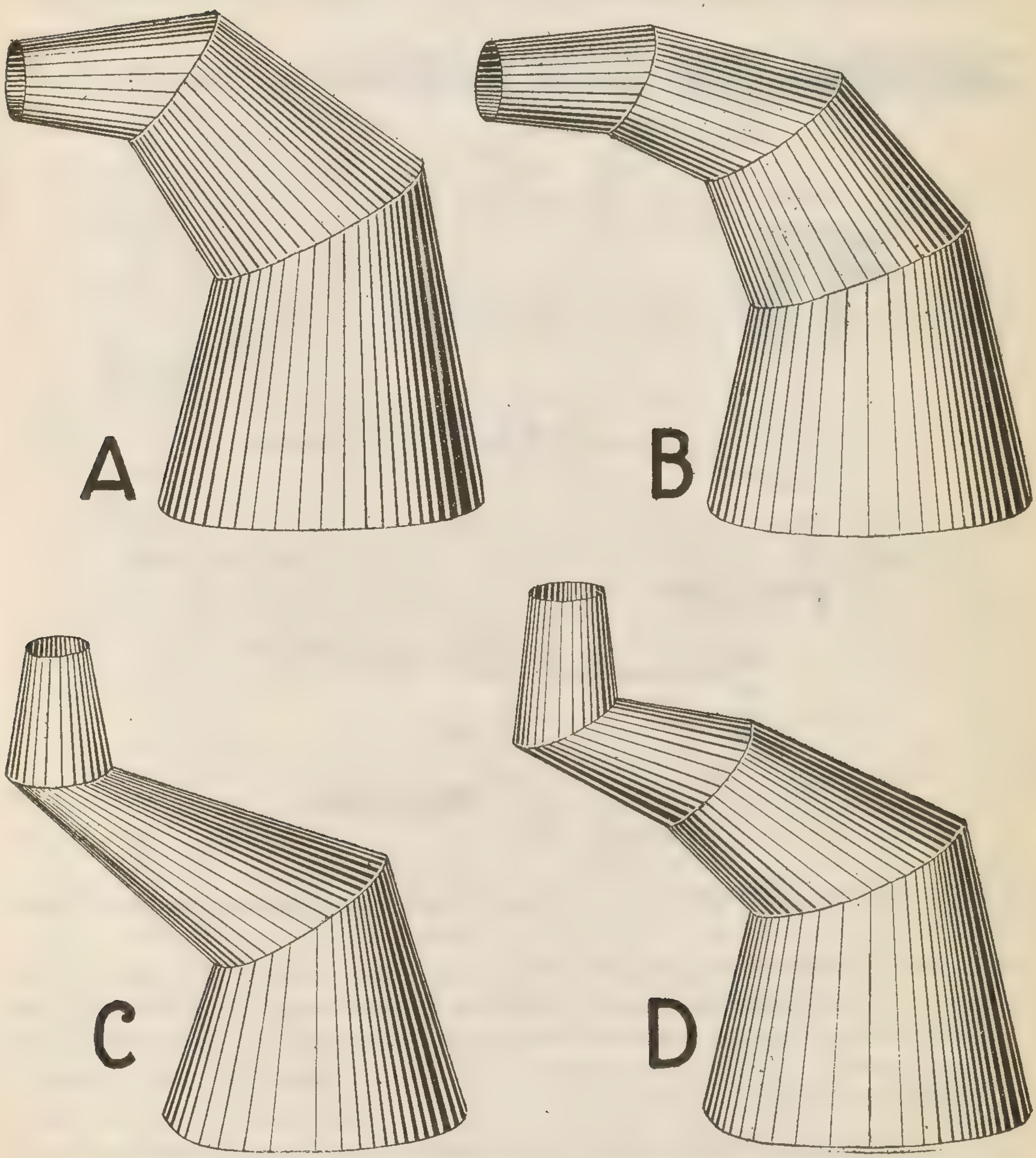
In this case the cross section of the gutter is represented at MBCN in elevation. The conical outlet which is to form a connecting piece between the gutter and the pipe, is a truncated cone whose wider end is shaped so as to conform with the surface of the gutter. The cone of which the connection piece is a part, is represented as BOC. The dotted line BC, represents the diameter of the base of this cone; the circumference of it being shown in plan.

To develop the pattern, first develop the truncated cone ABCD, obtain



FIGS. 9,595 to 9,598.—***Problem 30.*** Conical eave trough outlet and development of its pattern.

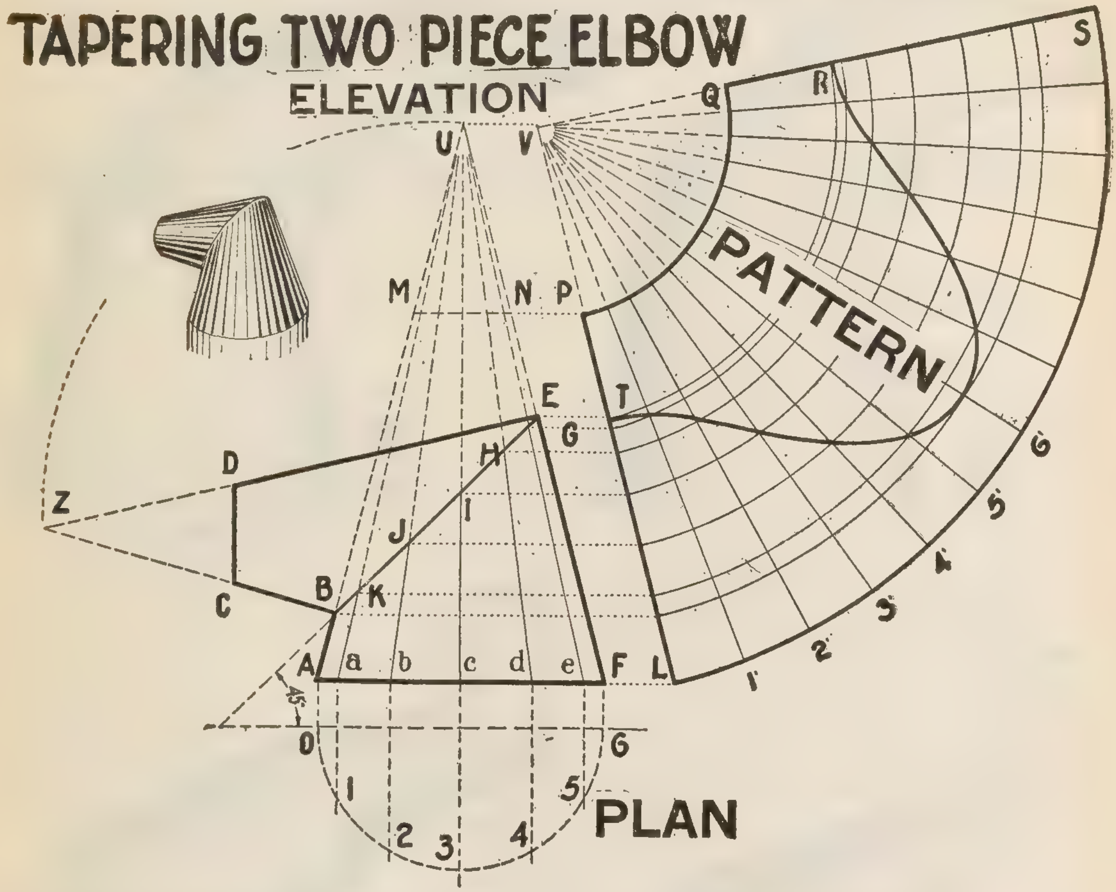
TAPERING ELBOWS



FIGS. 9,599 to 9,602.—***Problems 31 to 34, for practice.*** **A,** 3 piece elbow; **B,** 4 piece elbow; **C,** 3 piece offset; **D,** 4 piece offset.

the figure bounded by the radial lines HI, and GF (each equal to AB), and by the arc IKF and HG, the larger arc described with a radius equal to OB, while the smaller arc has a radius equal to OA.

The length of the larger arc is equal to the sum of all the divisions on the circumference of the circle shown in plan. These divisions are marked on



FIGS. 9,603 to 9,606.—*Problem 35.* Tapering two piece elbow and development of its patterns.

the development by the points 1′,2′,3′, etc. The points 1,2,3, etc., on the base line BC, being connected with the vertex O, by straight lines, the surface of the cone appears with a series of elements or lines converging in the vertex. On the development of the cone, these elements appear as the radiating lines S1′,S2′,S3′, etc.

Where the elements of the cone are intercepted by the cross section of the gutter, there are the points B,*a*,*b* and *c*, which are projected to the line FG, by projectors parallel to BF, thus marking off on the line GF, the points F,*a*′,*b*′ and *c*′. From these points, describe the arcs *a*′*e*,*b*′*f* and *c*′*h*. These

arcs, in their intersections with the lines S1′,S2′,S3′, etc., define the curved outward boundary FLKJI, of the required pattern.

Of course, the actual pattern should be enlarged along the curved boundary by the addition of stock for laps or locks.

Problem 35.—Patterns for a tapering two piece elbow. Figs. 9,603 to 9,606.

The pattern for this elbow is made up of the two halves of a truncated cone, which is cut into two parts by a 45° miter angle.

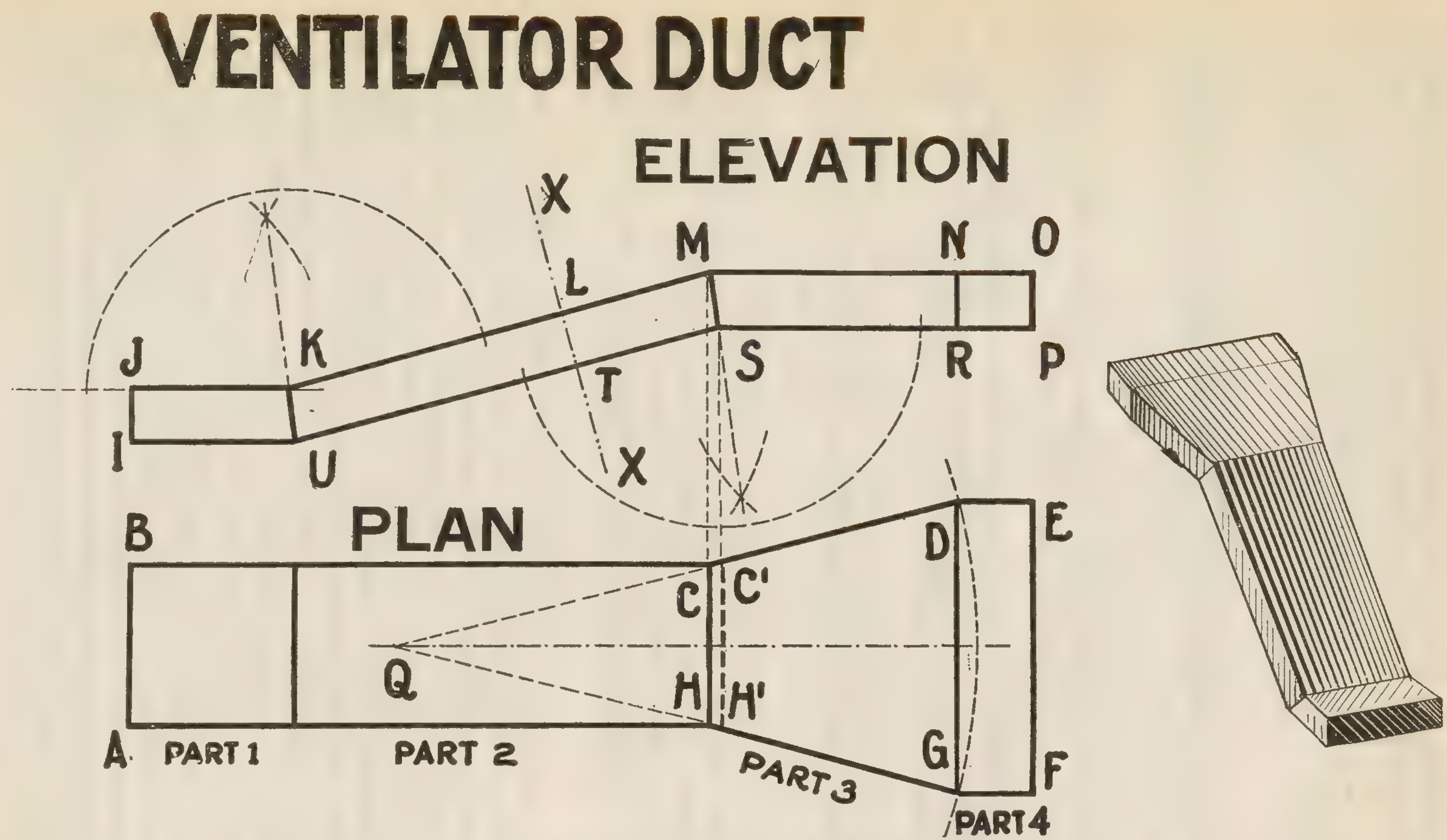
In the elevation AMNF, is the truncated cone cut by the miter from B to E. The upper part BMNE, of the truncated cone, when joined to the lower part, gives the horizontal part BCDE, of the elbow.

To obtain the desired pattern, begin by developing the truncated cone, using the method explained for the problem of the conical base for a pipe (problem 25).

In the development, LPQS, represents the development of the truncated cone. What now remains to be done is to divide this pattern into two parts, corresponding to the two parts of the elbow. This is accomplished by laying out, upon the development, the curved line TR, which is the upper boundary of the development of the obliquely cut, lower part ABEF, of the cone.

The divisions upon the circumference of the base circle and the corresponding radiating lines upon the surface of the cone used for the development of the cone, serve also for the development of its oblique lowest portion. These lines AU,*a*U,*b*U, etc., cut the miter line in the points B,K,J, etc. From these points, horizontal lines are drawn to the boundary line TL of the development, from whence arcs are described upon the development. These arcs, at their meeting points with the radial lines VL,V1′, V2′, etc., upon the development, define one half of the curve TR. The other half of this curve is an exact counterpart of the first and is laid out in a similar manner.

Although the development of the two parts of the elbow are plotted with the common curved edge TR, in shop practice, when a strip of stock has to be provided on one of the patterns, for joining purposes, along this curved outline, the two patterns have to be cut detached, with the aid of templates each of which is identical with the corresponding part of the development.



FIGS. 9,607 to 9,613.—***Problem 36.*** Four part ventilation duct and development of its patterns.

Problem 36.—Patterns for a ventilator duct. Figs. 9,607 to 9,613.

First draw plan and elevation. The duct as shown in the plan has four parts. Horizontally, all four parts are lying in one direction, as is seen in the plan. This view also shows that part three is a tapering part.

The elevation shows that part two rises obliquely while all other parts are situated horizontally. The elevation, furthermore, shows that all four parts have the same height, namely, equal to IJ, or OP. To insure equal heights in the two adjoining horizontal and oblique parts, the angle between them is bisected so that the joint between them falls upon the bisecting line. Thus the joint KU, falls within the bisecting line of the angle JKM. For the pattern of part one, draw the vertical line 5,10, upon which measure consecutively the width 10,8, the height 8,1, the width once more (1,2) and the height once more (2,5). At the points 10,8,1, etc., draw five indefinitely long horizontal lines, all at right angles to the line 10,5. Upon the horizontal lines, make 10, 9, 87 and 56 equal to JK, and measure the distances 14 and 23, equal to IU. Connect 6,3,4,7,9, completing the pattern for part 1.

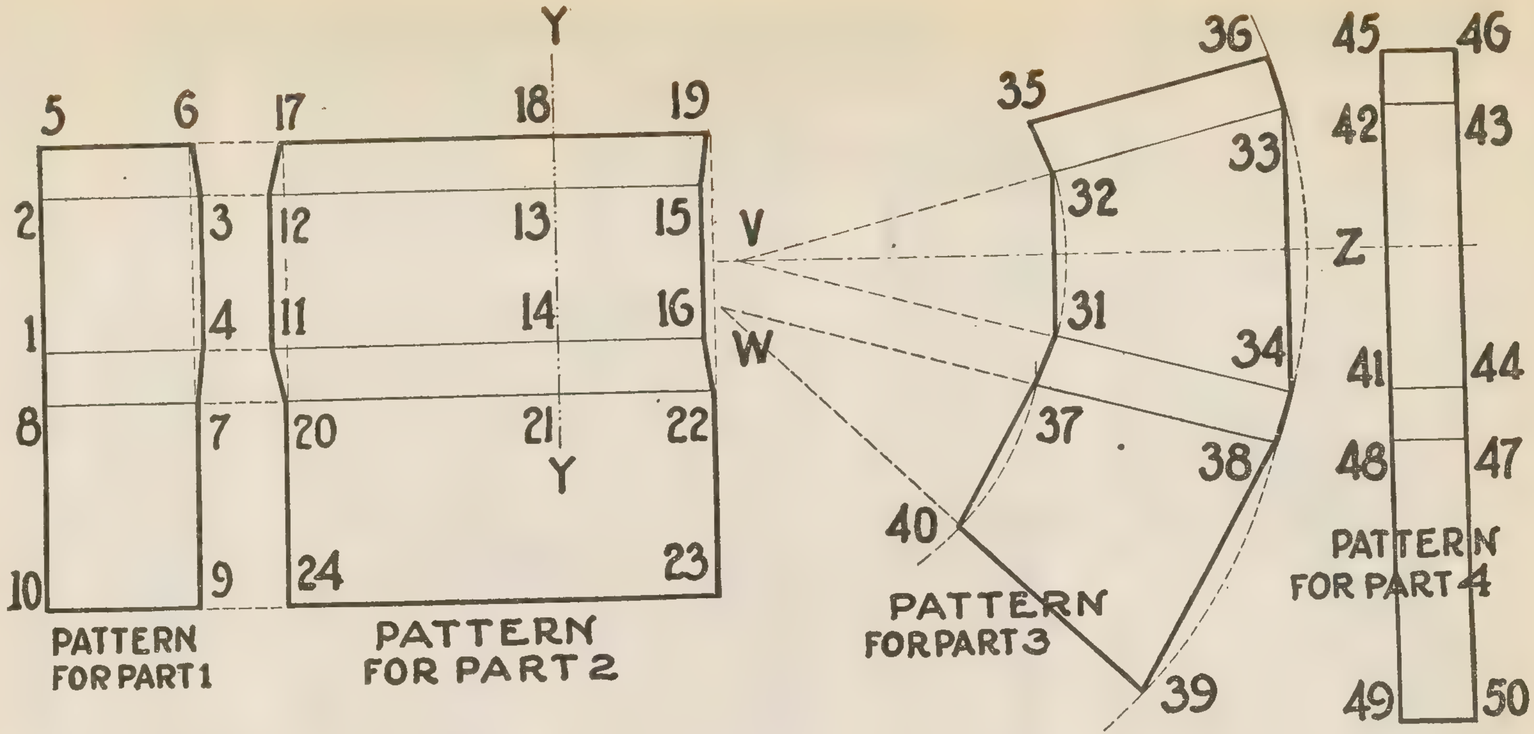
The pattern of the second part of the duct may be laid out on the same horizontal lines, however, to begin with, cross part two, in the elevation, by a line at right angles to it, at any point, say at L. Let this "stretch-out" line be XX. Now, returning to the five horizontal lines extending from the pattern of part one, cross the upper four of these lines, at any point, say at point 18, by a vertical line YY.

Now, starting to measure from the vertical line YY, upon the horizontal lines, set off 18, 19 and 21,22, each equal to LM. Also, starting from line YY, measure 13,15 and 14,16, equal to TS. On the same lines, then, make 12,13 and 11, 14, each equal to the line UT, also, make 20,21 and 17,18, each equal to KL. To complete the pattern for part two, draw the lines 20, 24 and 22,23, at right angles to the line 20,22. If properly constructed, the points 24,20 and 17, will be found lying in one vertical line. Similarly, the points 23,22 and 19, should fall within one vertical line.

For the pattern of the tapering part, reproduce, to start with, the angle GQD, together with its center line, at any convenient place, say at 34,V,33. With a radius equal to QD, reproduce the arc DG, at 33,34, from V, as center. Make 33,34, equal to GD, one half of it on each side of the center line VZ. Then make 33,32, equal to DC; also equal to 31,34. The figure 31,32,33,34, forms the bottom part of the tapering section of the duct. Adjoining each side of this, construct the upright walls of this section, as follows:

At 34, draw line 34,38, at right angles to line 31,34. From point 38, then, pass the line 37,38, parallel to 31,34 and make the distance 37,38, equal to CD. Similarly, the line 33,36, is at right angles to 33,32, the line 35,36, parallel to 32,33, the length 35,36, equal to MN.

Now, for the upper (horizontal) wall of the tapering section, extend the line 37,38, and make 38,W, equal to D Q. With this distance as radius,



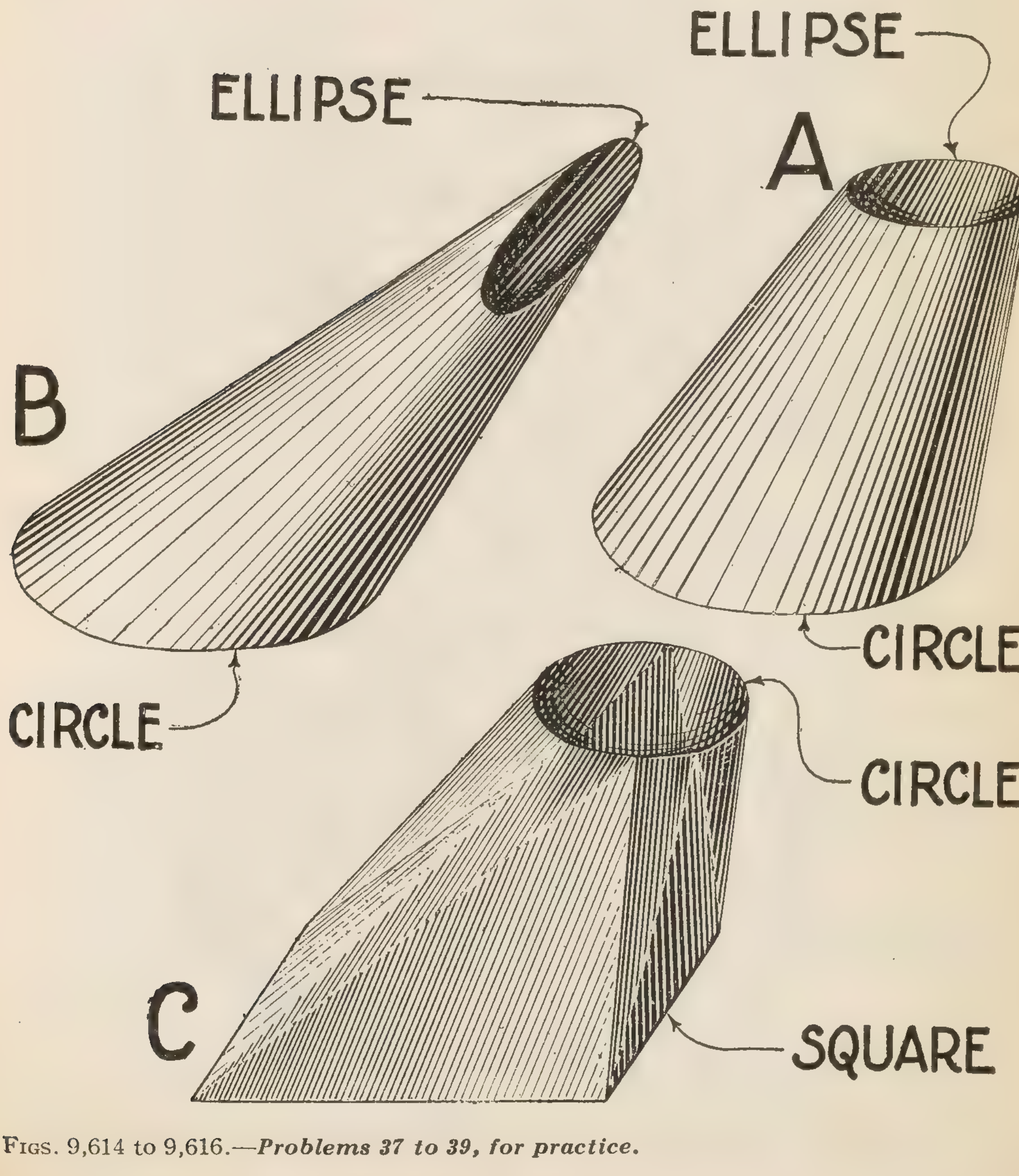
Figs. 9,607 to 9,613.—*Problem 36.—Continued.*

describe the arc 38,39. Then, from point 38, with a radius equal to 33,34, strike off upon the arc the distance 38,39. Then, having connected 39, and W, by a straight line, cut this line at the point 40, with the arc 37,40, whose center is at W. Note, the arcs 37,40, and 32,31, are not of equal radii.

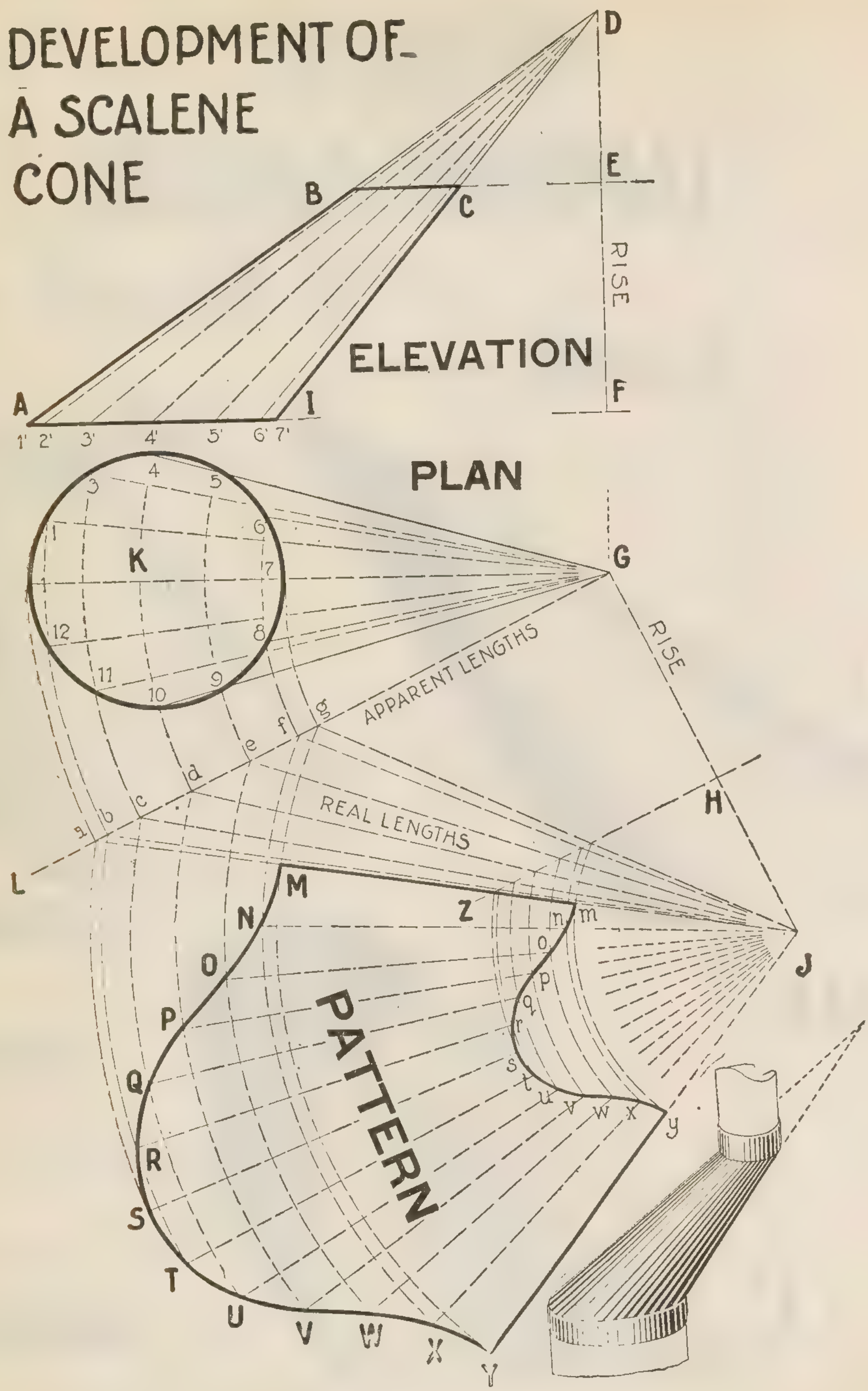
The pattern for the fourth part of the duct, 49,45,46,50, is a rectangle wherein 45,46, is equal to PO, whereas 45,52, equals 36,33; 42,41, equals 33,34; 41,48 equals to 34,38 and 48,49 equals 38,39.

All patterns have to be provided with laps for joints.

OBLIQUE TAPERING FLANGES



Figs. 9,614 to 9,616.—*Problems 37 to 39, for practice.*



FIGS. 9,617 to 9,620.—***Problem 40.*** Scalene cone and development of its patterns

Problem 40.—Patterns for a scalene cone. Figs. 9,617 to 9,620.

In the plan, divide the circular base into any number of equal parts by the points 1,2,3, etc. Project these points up to the base line AI, of the cone, obtaining the points 1′,2′,3′, etc. Connect all these points with the vertex D, by means of straight lines giving the elementary lines D1′, D2′, D3′, etc.

Since these elementary lines (with exception of D1′, and D7′) appear shorter than their actual lengths, find their actual lengths by constructing a series of triangles, according to the following rule:

For finding the real length of a line given only in apparent length in the plan view and in the elevation, there is the following important rule: Construct a right angle triangle one of whose legs, make equal to the apparent length of the given line as seen in the plan and, the other leg, make equal to the vertical height which the given line rises in its position in the elevation. The hypotenuse is the real length of the given line.

Accordingly, lay off the right angle LGJ, for the required right angle triangle. Upon the line LG, set off the distance Gf, equal to the apparent length 8G (in plan), as one leg of the triangle. The same line appears in elevation as 6′D; it rises in a vertical plane, from the level of the line 6′F, to the vertex D, that is, its vertical rise is equal to FD. This rise set off from G to J, to form the second leg of the triangle. The line joining the points *t* and J (the hypotenuse of the triangle *t*GJ) is the real length of the line 6′D (or 8G).

In a similar manner other real lengths as *e*J, *d*J, *c*J, etc., are obtained.

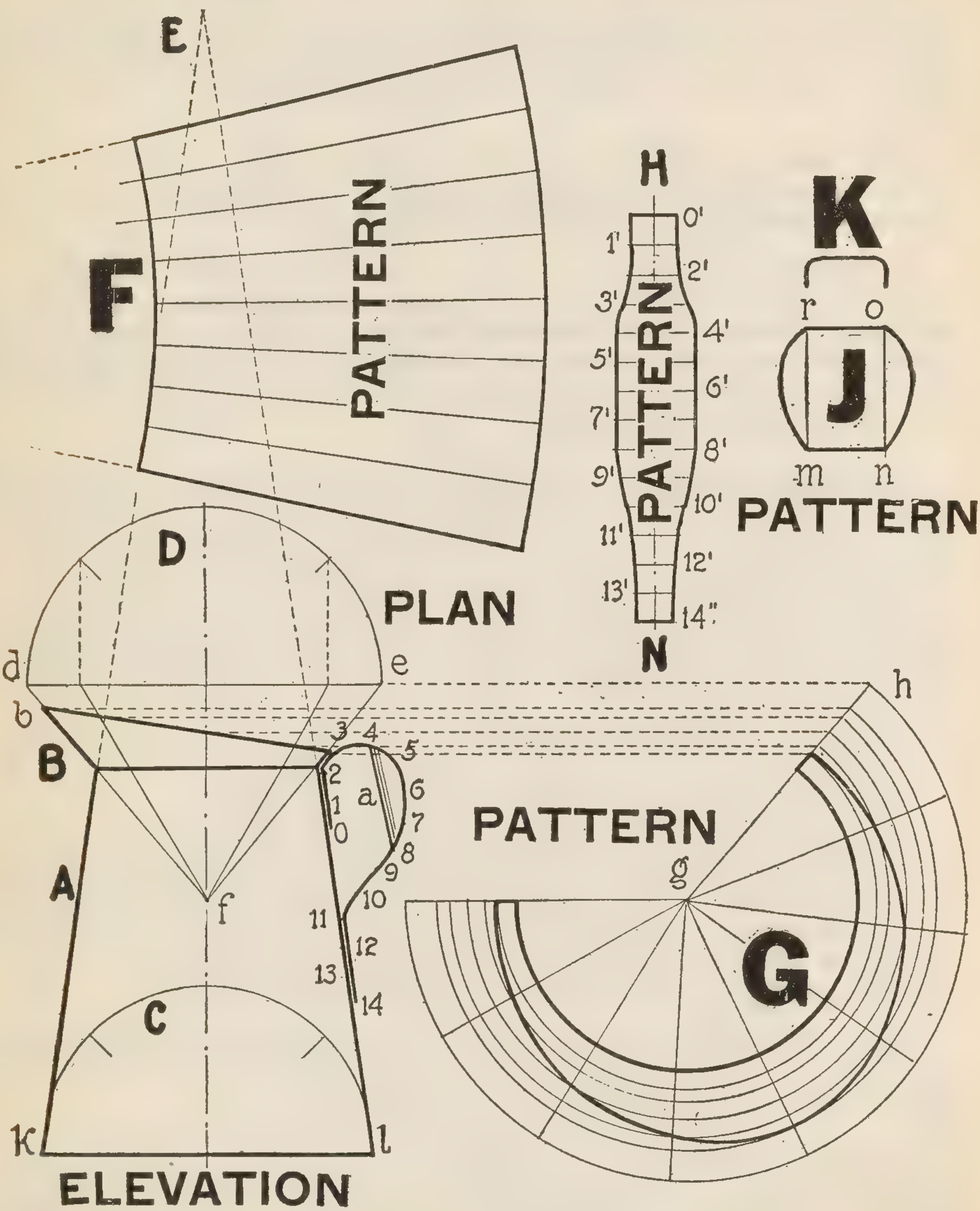
Describe from J, as center, arcs through *g*,*f*,*e*, etc.

To lay out the required pattern, describe, from J, as center, the arcs *g*M, *f*NX, *e*OW, etc. Then, from point M, as center, with a radius equal to *one of the divisions* on the base circle, step from arc through *g*, to the next arc, at the point N. Then, from the point N, with the radius equal to division of the base circle, step to the next arc at the point O, and in a similar way obtain the other points which define the curve.

The drawing plainly shows how the second half of this curve is plotted on the above arcs so as to form an exact counterpart to the first half of the development all the points gives the curve MSY.

The joining development of the top BC, is the curve *msy*, obtained in a similar manner. These two curves and the radial lines M*m* and Y*y*, complete the pattern, with exception of proper laps which must be added for the joints.

PATTERNS FOR A FLARING MEASURE



FIGS. 9,621 to 9,627.—*Problem 41.* Flaring measure and development of its patterns.

Problem 41.—Patterns for a flaring measure. Figs. 9,621 to 9,627.

To save space some of the drawings overlap, however, this need not cause confusion, and the student should become accustomed to reading drawings which overlap.

The patterns for the flaring measure are laid out according to the rules explained for the development of cones and truncated cones.

The cone of which the body of the measure forms a part is shown in the elevation as *k*E*l*, while its truncated part, the body of the measure, *k*B2*l* is developed at **F** (only a half of the development is here presented). The outer arc of this development has a radius equal to *k*E, the inner arc, a radius equal to *k*B. The length of the outer arc is made equal to the circumference of the base circle C, of the cone.

The lip B*b*32, is a part of an inverted cone *fde*, the development of which is given at **G.** In the development the outer arc is drawn with a radius *gh*, equal to *fd*, the length of this arc being equal to the circumference of the circle D, the base circle for the second cone. The equal divisions upon this circle projected to the edge of the lip *b*3, give a series of points which are in turn, projected to the line *gh*, there giving starting points for the arcs upon the development of the lip, the curve for which is obtained by means of intersections of these arcs with the radial lines drawn to the points upon the outer arc where the equal divisions taken from the circle D, were consecutively set off.

To plot the pattern for the handle, divide its profile into a number of equal parts, 1,2,3, etc. Then, set off these divisions one next to the other a line HN, which is to serve as a center line for the pattern of the handle. Through the divisions upon this center line draw, at right angles to it, a number of perpendiculars upon which lay off the widths of the handle at the different parts of it, always one half of the width to each side of the center line.

Thus the outline 0′,14,13,1 will furnish a symmetrical shape.

The boss, added to the handle at *a*, is made of a piece shown at **J** and and at **K.** In this piece, the rectangle *mron*, is made as wide as the handle at the place where the boss is attached. The height of this rectangle, *mr* is equal to the shortest distance between the points 8 and 4, on the profile of the handle. The irregularly shaped parts to each side of the rectangle *mron*, are exact reproductions of the shape enclosed by the line 9*a*4, and the curve 45678, in the elevation of the measure.

At **K**, is shown the manner in which this boss is to be bent. This is an easily obtained pattern for the boss. Where it is required to give the boss a wholly rounded bend, its pattern will take the shape of an oval whose length and width may be made equal to the above boss.

Measures are made in many different shapes and proportions, by different manufacturers. However, while there is no national standard for flaring measures, it might be helpful to keep in mind the proportions recommended by the U. S. federal government. According to these, the bottom and top diameters should be designed in a definite ratio to the perpendicular height of the measure, namely, the bottom base should be made two thirds of the vertical height (in diameter) while the top base should be made two thirds of the bottom base, in diameter. As to the vertical height, it should be 9.8 in. for a gallon measure; 7.78 in. for a half gallon measure; 6.17 in. for a quart measure; 4.90 in. for a pint measure; 3.89 ins. for a half pint measure and 3.09 in. for a one gill measure.

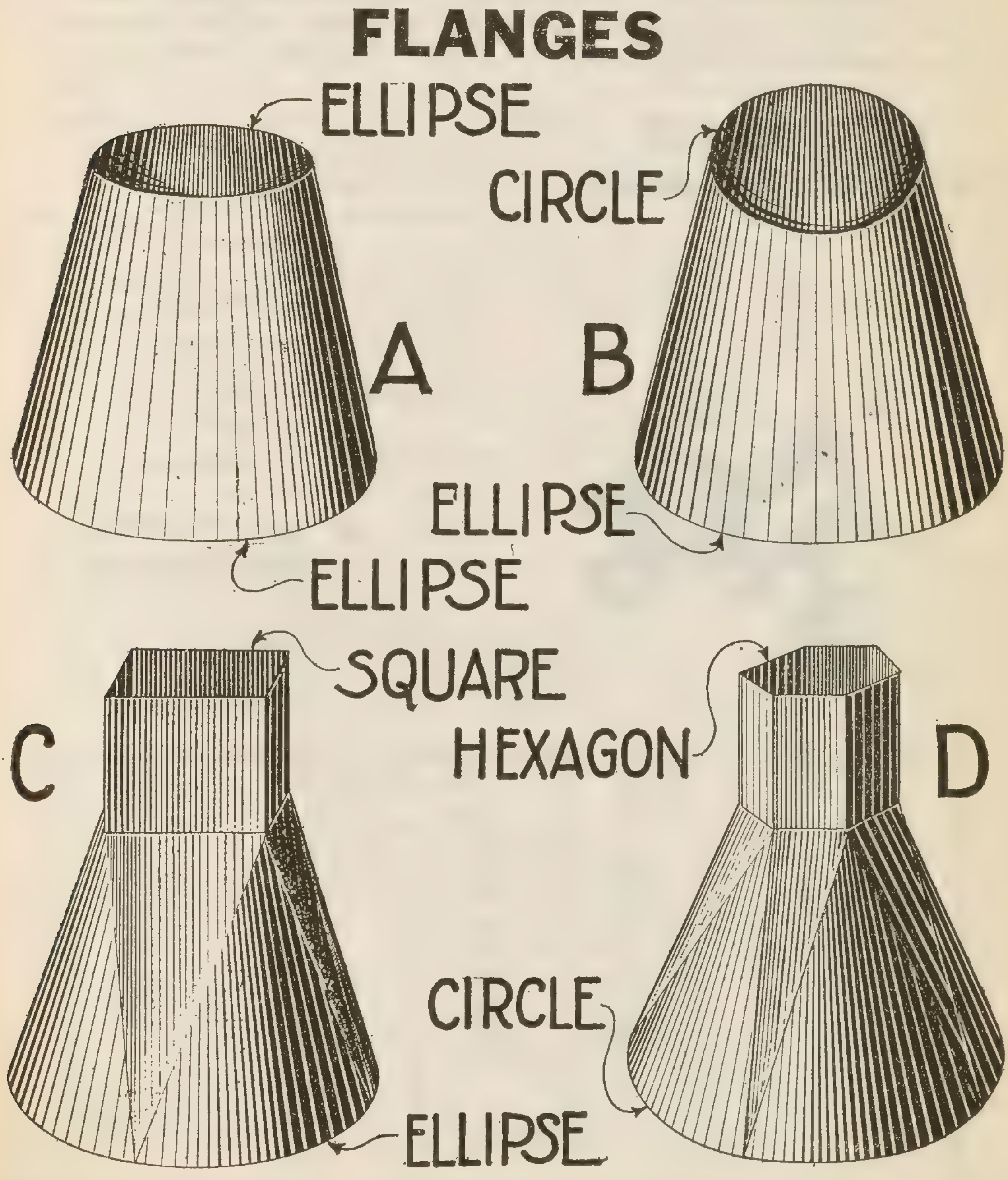
Development by Triangulation

There is a third class of elementary surfaces which contains neither parallel nor radial elements. If is found, however, that on such surfaces a series of two or more elements may be drawn in certain directions forming angles.

On such irregular surfaces it may happen that no two of the angles thus drawn on the solid, or represented, either correctly or foreshortened, in the projection draiwng, will lie in the same plane or be equal to each other. Since it is possible thus to project these angles, evidently they may be reproduced on the flat surface of the drawing paper in their correct size. If this can be done, it may be reasonably assumed that the surfaces thus represented will be the same as the corresponding surface of the solid surfaces belonging to the class and developed by the method of triangulation, and to the student who thoroughly understands the principles of projection, present no serious obstacles.

This process of triangulation depends on two operations.

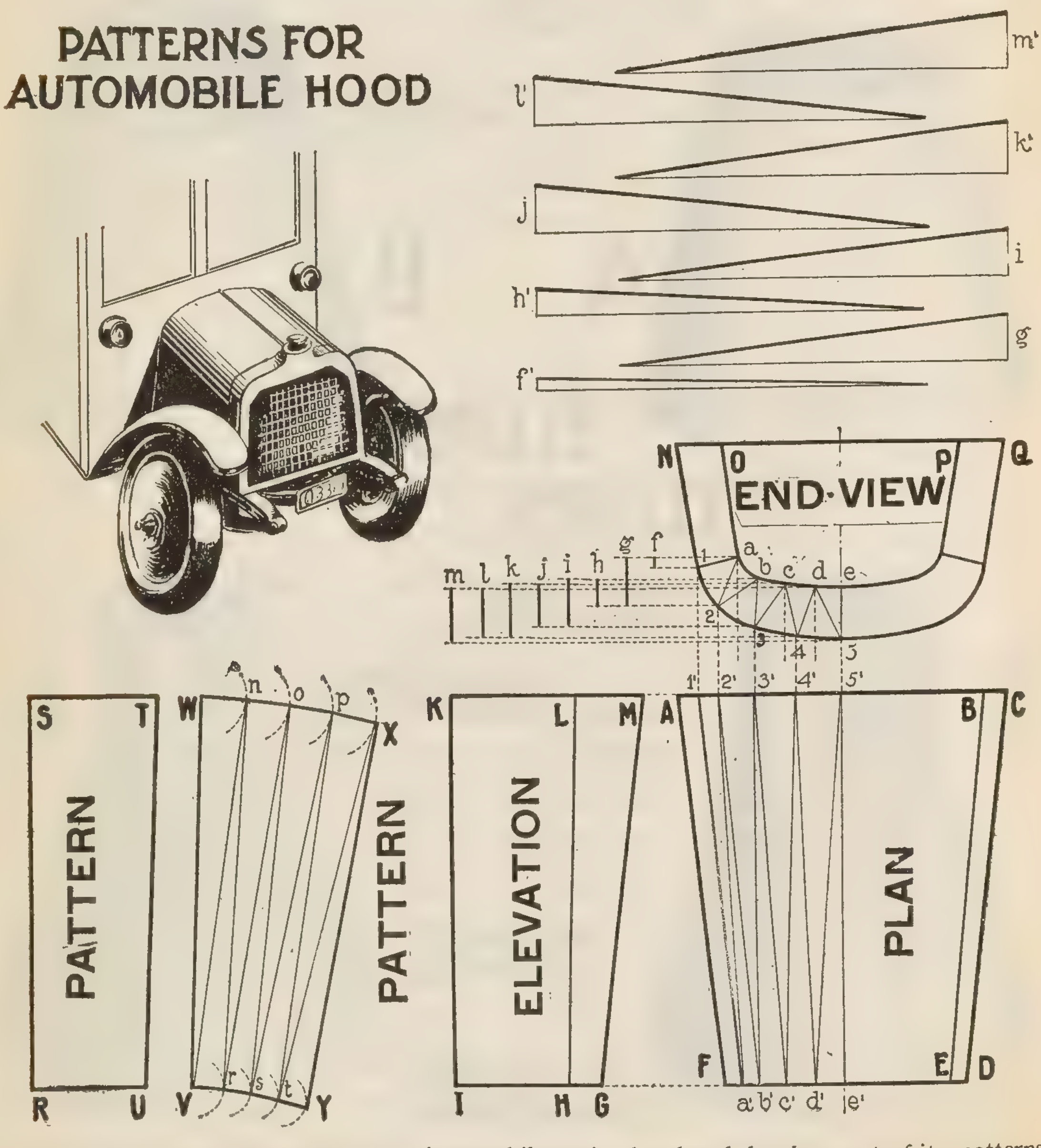
1, Finding the true length of all lines, real or assumed, appearing on the surfaces of the solid, and 2, constructing triangles similar in form and relation to those shown on the solid.



FIGS. 9,628 to 9,631.—***Problems 42 to 45, for practice.***

Problem 46.—Pattern for automobile engine hood. Figs. 9,632 to 9,645.

The *hood* or cover is made up of two rounded top parts and two flat parts. In the side view, IKLH, shows one of the flat parts, foreshortened. The real length of IK, is equal to FA (in the top view), the line IH, appears in true length as *a*O, and the line KL, as 1N, in the front view.



Figs. 9,632 to 9,645.—***Problem 46.*** Automobile engine hood and development of its patterns.

The pattern for the flat part is drawn by making the line RS, equal to AF, then erecting the lines RU (equal to *a*O), and ST (equal to 1N), perpendicular to RS, and finally joining the points U and T, to complete this pattern.

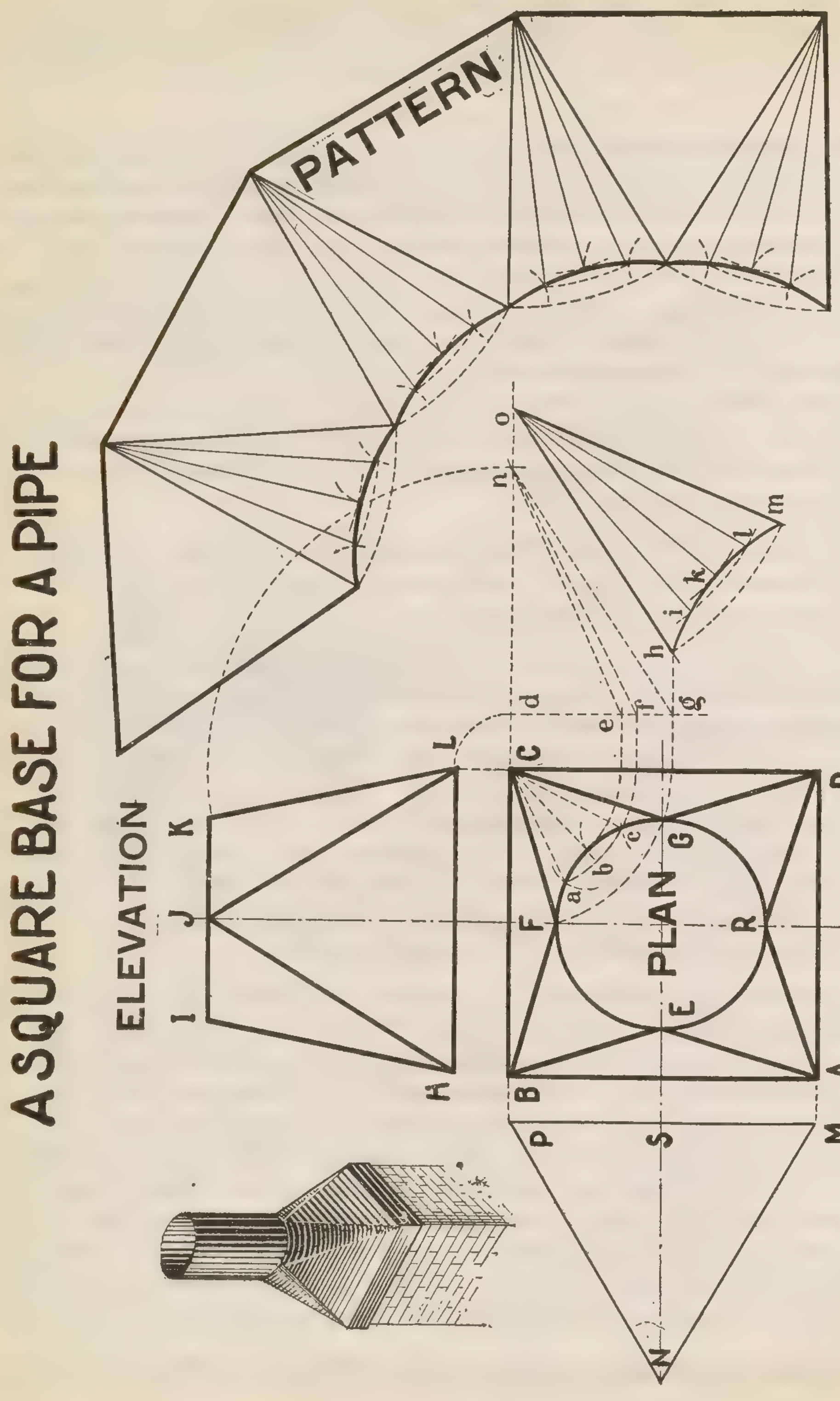
The rounded part designated in the front view of *abcde* 54321, and in the top view as *a′b′c′d′e′* 5′4′3′2′1′, is divided (applying the method of triangulation into a suitable number of triangles which, when put together in their true shape and proper order, will furnish the desired pattern. The smaller curved outline of the cover is divided into a number of equal parts, by the points *a,b,c,d,e*. The larger curve too is divided into the *same* number of parts, by the points 1,2,3,4,5. The divisions *a,b,c,d,e* are projected upon the edge FD, in the points *a′b′c′d′e′*, while the divisions 1,2,3,4,5 are projected to the edge AC, by the points 1′2′3′4′5′. Connecting these points, seven triangles are obtained upon the one half of the rounded part of the cover. These triangles appear in the front view greatly foreshortened, bounded by the lines 1*a*,*a*2,2*b*, etc.

For the purpose of obtaining the true lengths of the sides of all the triangles, determine the vertical rise of each. The end view shows that for the line 1*a*, the rise is *f*, for the line *a*2, the rise is *g*, etc.

Finally, the rise of *e*5, is equal to its length since the line is vertical. The true length of the line 1′*a*′, is equal to the hypotenuse of a triangle, one of whose legs is the apparent length of the line 1′*a*′, and the other leg, the rise of this line as appearing in the other view. The rise for this line is *f*. The true length of the line appearing as *a*′2′, again, is the hypotenuse of a triangle one leg of which is the apparent length *a*′2′ and the other leg, the rise of the same line as it appears in the other view, this time equal to *g*. Similarly, for all the remaining lines. The illustration shows the rectangular triangles built to obtain the true lengths of the eight lines, 1′*a*′, *a*′2′, 2′*b*′, etc. The true length of the line 5′*e*′ is equal to GM.

Now proceed to put together all the triangles with their sides drawn in their true lengths as follows: Make the line VW, equal to the true length of the first line, 1′*a*′ (equal to the hypotenuse of triangle 8) describe an arc from W, as center, with a radius equal to 12, (measured on the larger curved profile in the front view), and intersect this arc, in the point *n*, by another arc, described from V, as center, with a radius equal to the length of the next line *a*′2′, thus completing the first triangle. Then, from V, as center, describe an arc with the length of *ab* (measured on the smaller curved outline, in the front view) and intersect this arc at the point *r*, by means of another arc drawn from *n*, as center, with a radius equal to the third line 2′*b*′, thus completing the second triangle.

The remaining triangles necessary to complete the pattern VWXY, are



Figs. 9,646 to 9,651.—*Problem 47.* Square base of a pipe or transition piece between square and round pipes and development of its patterns.

obtained in a similar manner. The pattern thus obtained forms one half of the rounded part of the hood.

Problem 47.—Pattern for square base of a pipe, or transition piece between square and round pipes. Figs. 9,646 to 9,651.

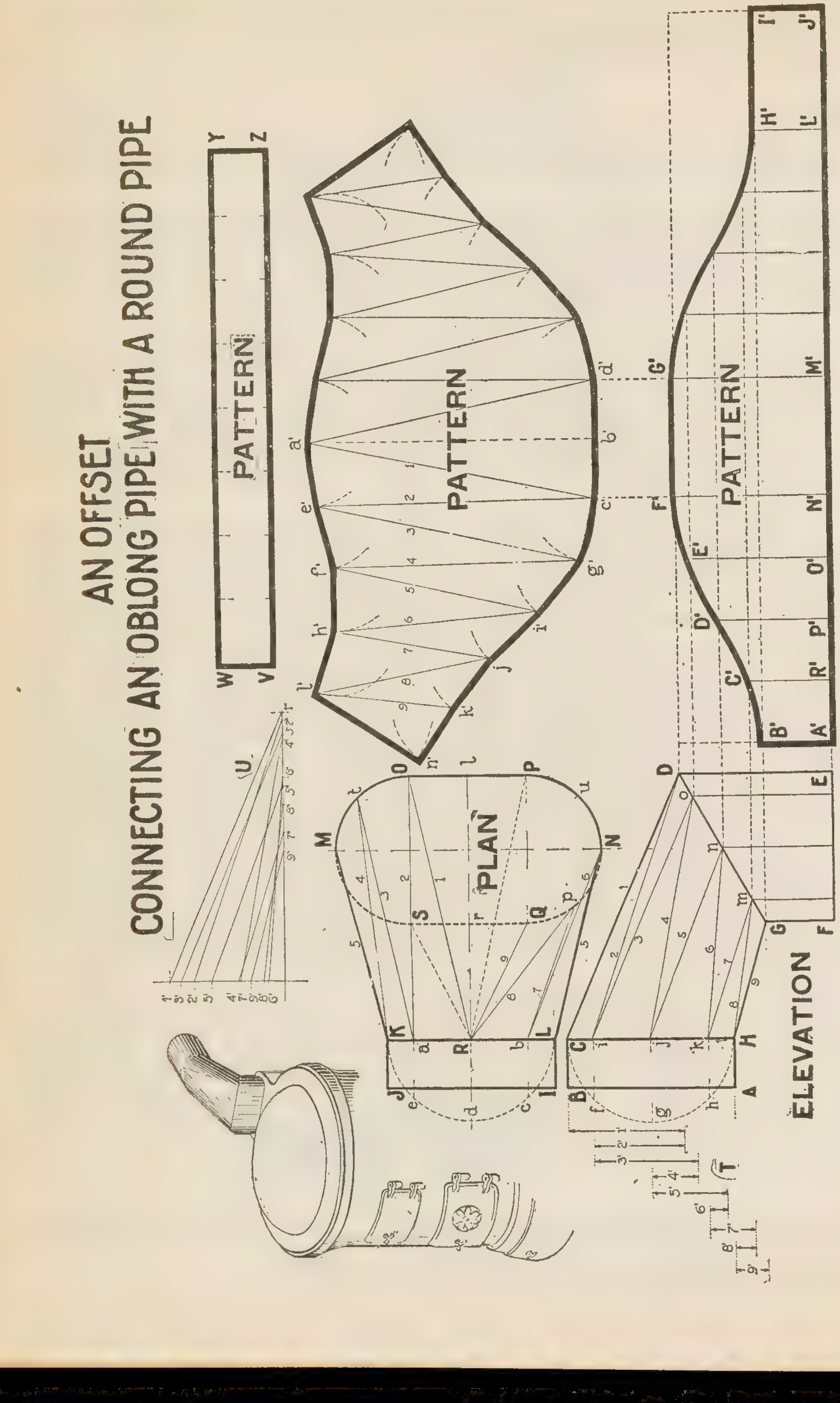
The square base is made up of four plane triangles whose adjoining base lines AB,BC,CD, and AD (in plan), form the square ABCD, at the bottom, and of the four irregularly shaped triangular corner pieces which occupy the spaces between the sides of the four plane triangles.

The four plane triangles appear in the plan as AEB,BFC,CGD and ARD. These triangles appear foreshortened because they stand oblique. HI (or LK), shows the actual height of these triangles. Hence, to obtain the actual shape of one of these triangles, make MP, equal to AB, and SN, equal to HI. The triangle MNP, then, gives the pattern for one of the four equal plane triangles.

The four irregularly shaped corner A pieces, EAR, EBF, FCG, and GDR, can be developed by triangulation. The pattern for one for one of them is shown as *ohiklm*. This pattern was obtained by triangulating the corner piece FCG, as follows: The arc FG, was divided into four equal parts at points *a*, *b*, and *c*, by means of which divisions the corner piece FCG, was subdivided into the four triangles FC*a*, *a*C*b*,*b*C*c* and *c*CG. To lay out these triangles in their real sizes, the real lengths of their sides were constructed, as *gn*, which is the real length of GC (also of FC); *fn*, which is the real length of *c*C, or of *a*C and, *n*, which is the real length of *b*C. The pattern of the corner piece *hom*, has the edge *oh*, equal to *gn* and the arcs *ohm*, with a radius equal to *oh*, the arc *il*, with a radius equal to *fn*, and the arc *k*, with a radius equal to *en*. Set off the length of the line *oh*, and then with a radius equal to F*a*, step from the point *h*, to the next arc, at the point *i*; then, from point *i*, with the same radius, step to the next arc at the point *k*; then, from point *k*, with the same radius, step to point *l* and thence, finally, to point *m*.

The illustration shows how the component four patterns of the plane triangles, and the patterns of the four corner pieces, are joined together so as to produce the entire pattern of the required square base for the round pipe. As a rule, however, the pattern is too large to be constructed of one piece of sheet metal. Hence it is usual in practice to plot the pattern for only a quarter or one-half of the entire pattern.

Problem 48.—Patterns for an offset connecting an oblong pipe with a round pipe. Figs. 9,652 to 9,658.



FIGS. 9,652 to 9,658.—*Problem 48* Offset connecting an oblong pipe with a round pipe and development of its patterns.

The offset consists of three quite different parts. First, the oblong part in the plan by the letters NQSMOP; secondly, the oblique part, indicated by NLKMOP, thirdly, the cylindrical collar IJKL.

The oblong part is made up of two half cylinders QNP and SMO, connected by the two flat sheets QS and PO. The first of these flat sheets QS, appears in the elevation as the line FG, the second, as ED. Between the lines FG and ED, there is the half cylindrical part FGDE. Its pattern is developed exactly as in the case of all cylindrical elbows, by taking the edge GD, as miter edge.

The circumference of one of these semi-cylinders (in plan) is then divided into a number of equal parts, as at Q,*p*,N,*u*,P. From these dividing points, projection lines are drawn upon the elevation of the semi-cylinder EGDE, cutting the miter line GD, in the points G,*m*,*n*,*o*,D.

Then, to develop the pattern of the oblong part of the offset, draw the line A′J′, as a continuation of the line FE, and upon it set off the circumference of one of the semi-circular bases of this part, from A′, to N′, consisting of all the equal divisions in the semi-circle QNP; next, upon the same line, lay off N′M′, equal to the length PO, of the flat part; next, once more all the parts of the semi-circle, from M′ to L′; finally, the distance L′J′, equal to N′M′. Then erect perpendiculars to the stretchout line A′J′, from all its division points, R′,P′,O′, etc. These perpendiculars, intersected by projection lines that start from the several points on the miter line, from the points G,*m*,*n*,*o*,D, define the pattern A′B′D′F′G′I′J′, for the oblong part of the offset.

The oblique part, at one end, conforms to the oblong part, while at the other end it becomes circular so as to be joined to the cylindrical collar.

The irregular shape of this oblique part is developed by triangulation.

Not all of the surface of the oblique part of the offset is rounded. Namely, the portions of it that adjoin the flat sections of the oblong pipe being by necessity flattened, there are two corresponding flat portions upon the surface: above, there is the large plane triangle PRO (see plan) and below, the smaller plane triangle QRS. Hence only the remaining two sections of the surface are rounded and subject to development by triangulation. These two portions are opposite each other and identical. One of these is bounded by the semi-circles QNP, of the oblong and the corresponding half of the circle of the collar which, seen edgewise, appears in plan as the line R*b*L. The other reversed, but identical in size and shape, is bounded by the semi-circle SMO, of the oblong and the corresponding half of the circle of the collar that is represented by the line R*a*K.

For purposes of triangulation, divide each half of the circumference of

the collar into as many equal parts as there are in the semi-circles QNP and SMO. In the plan, the divisions of the circumference of the collar are marked by the points L,*c*,*d*,*e*,K, which divisions are projected upon the edge LK, at the points L,*b*,R,*a*,K. The same divisions in the elevation are indicated by the points H,*k*,*j*,*i*,C.

Now, proceed to join the divisions on the semi-circles of the oblong pipe with successive points of divisions upon the edge of the collar, by straight lines which will furnish sides for the triangles with which the entire rounded portion of the oblique pipe will be covered. Obviously, on the outer side of the oblique pipe there will be longer triangles while on the underside of it will be shorter triangles.

The drawing shows only one half of the upper side and only one half of the underside subdivided into triangles; this to avoid unnecessary crowding and consequent confusion.

The triangles on the outer side are: RO*a*,*a*O*t*,*ta*K and K*t*M. On the underside the triangles are: NL*b*,*b*N*p*,*pb*R and R*p*Q. The long sides of the triangles are numbered in the illustration 1,2,3, etc. The same lines, upon the elevation are marked by the same numbers as in the plan. Of course, all these lines are given upon these views only in apparent, foreshortened lengths. Before using them for the spreading out of the triangles upon the desired patterns, the lines have to be determined in their real lengths. For this purpose, the rise of each line in one view, and its apparent length in the other view, are taken to supply the two legs of a right angle triangle whose hypotenuse will be equal to the real length of the line. The rise for each line of the elevation is given, in the drawing at T, where 1′, stands for the rise of line 1; 2′, for the rise of line 2, etc. At U, all the rise lengths are laid off as the upright legs of nine triangles, while the apparent lengths of the lines 1,2,3, etc., are laid off as horizontal legs. Thus, the hypotenuse 11′, represents the real length of the line 1; the hypotenuse 2 2′,represents the real length of the line 2, etc.

With the real lengths thus obtained, triangles are constructed that cover the oblique pipe, in their actual sizes,one next to another, to which will have to be added the two plane triangles PRO and QRS, that complete the surface of the oblique pipe.

The altitude of the larger of the plane triangles is reproduced at *b′a′*, upon the pattern. It is taken from the elevation where the edge CD, is equal to the true length of the altitude R1 (in plan).

The triangle *c′a′d′*, upon the pattern, represents the actual size of the triangle PRO (in plan), *c′d′*, being equal to the real length of PO, *d′a′* being equal to the real length of RO, each equal to line 1.

Now, with a radius equal to B′C′ (upon the pattern of the oblong pipe), and a', as center, describe an arc which is intersected at e', by another arc, drawn from c', as center with a radius equal to the true length of the line 2. Now from c', as center, with a radius equal to one of the equal divisions upon the circumference of the collar, say cd, describe an arc which intersects at the point g', by means of another arc, drawn from e', as center, with a radius equal to the line 3. In a like manner lay out all the other triangles of the surface of the oblique pipe. In the drawing the long sides of the different triangles are numbered the same as in the plan and elevation.

The distances $g'c'$, $g'i'$, $i'j'$, and $j'k'$, are each equal to one of the divisions of the circumference of the collar; on the opposite side of the pattern, the divisions $a'e'$, $e'f'$, $f'h'$ and $h'l'$, are equal in the same order, to B′C′, C′D′, D′E′ and E′F′. The triangle $n'l'k'$, is equal to the actual size of one half of the triangle RQS; the point n', is obtained by the intersection of two arcs, one, with a radius $k'n'$, equal to Qr, the other with a radius equal to the altitude of the triangle QRS, which is given in the elevation, in its true length, by the line HG. The other half of the pattern is a counterpart of the first and is constructed exactly like it.

The pattern of the collar is a straight band VWYZ, whose width VW, is equal to AH, and whose length is equal to the circumference of the collar.

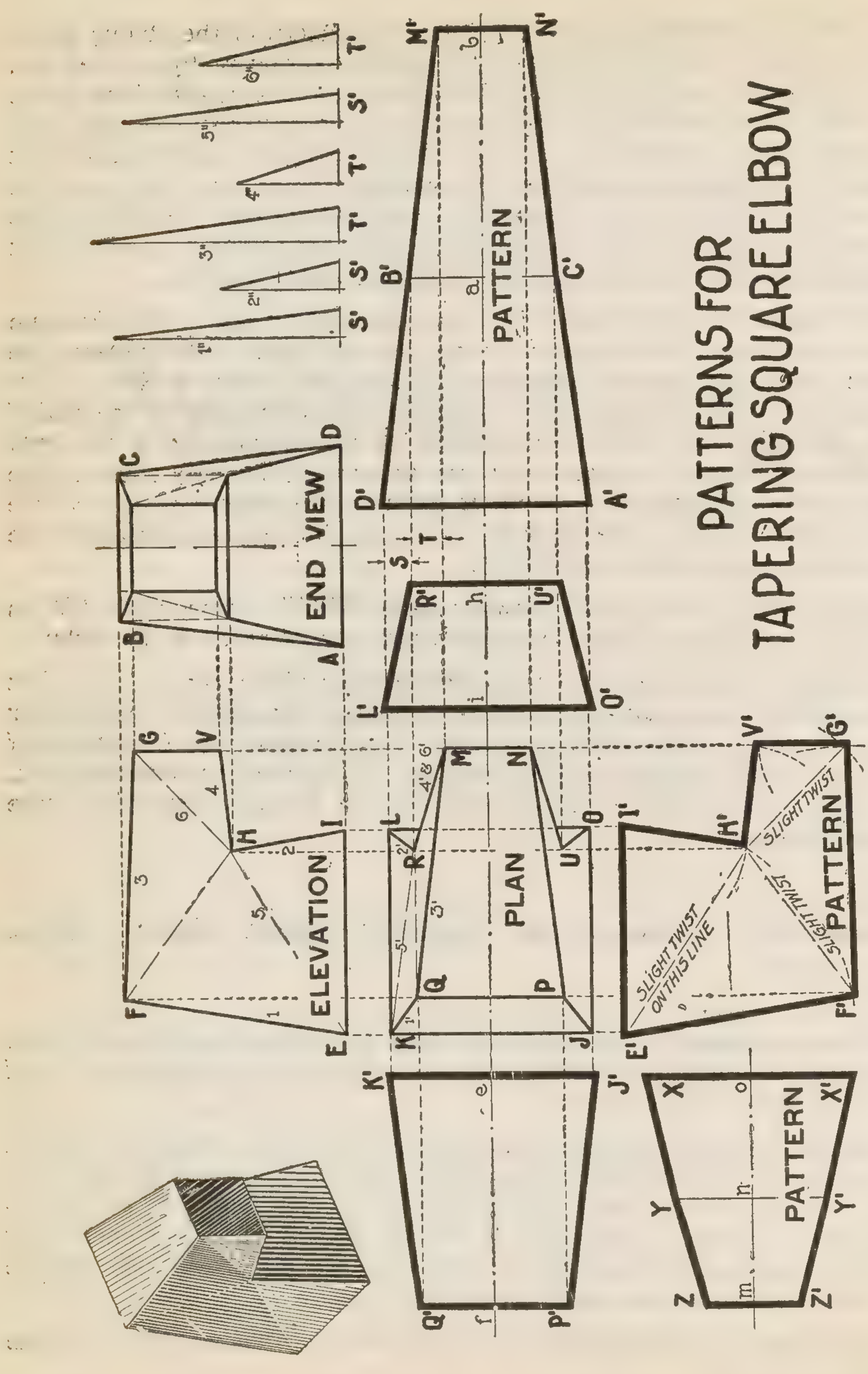
The method here employed for the development of the parts of the offset may be applied to a great many similar problems, for patterns of irregular elbows, transition pieces and, in general, for the plotting of patterns of irregularly rounded bodies or parts of bodies. Of course, the patterns must, in all cases, be enlarged by the addition of stock for flaps and locks, where such are required.

Problem 49.—Patterns for tapering square elbow. Figs. 9,659 to 9,673.

For shop purposes it will suffice to draw the side elevation and plan. Here, the front elevation is added to give a better idea, to the beginner, of the peculiar shape of the elbow.

The elevation shows, mainly, the large face EFGVHI, which is divided into triangles by the lines EH, FH and HG along which the metal has to be slightly twisted so as to enable the fitting of this one piece face to the adjoining sides and top. The pattern for this face is best constructed by means of triangulation, the method used for the development of the scalene cone, radiator cover, etc., in previous problems.

For purposes of triangulation, it is necessary to determine the **true**



FIGS. 9,659 to 9,673.—*Problem 49.* Tapering square elbow and development of its patterns.

length of the lines in the triangles that are to be used for making up the required patterns. For this, take the vertical rise of each line, in one of the views, as one leg, and the apparent length of each line, as it appears in the other view, for the other leg; the hypotenuse gives the true length of the line.

For convenience, the lines, whose true length must be found, are numbered, in the side view, as 1,2,3,4,5,6 and in the plan, as 1′,2′,3′,4′,5′,6′.

The rise of line 3′, is the same as that of the line RM, which latter represents two lines 4′ and 6′, which coincide in the plan. The rise for each one of these lines is equal to the distance marked T. The rise of 1′, is the same as that of line 5′, and also the same as the rise of line 2′. Each of these three lines rises by the amount indicated as S. These rises are used as the shorter legs for six right angled triangles, the other legs of which are made equal to the apparent lengths of the corresponding lines upon the side view, namely, the legs 1″,2″,3″,4″,5″,6″.

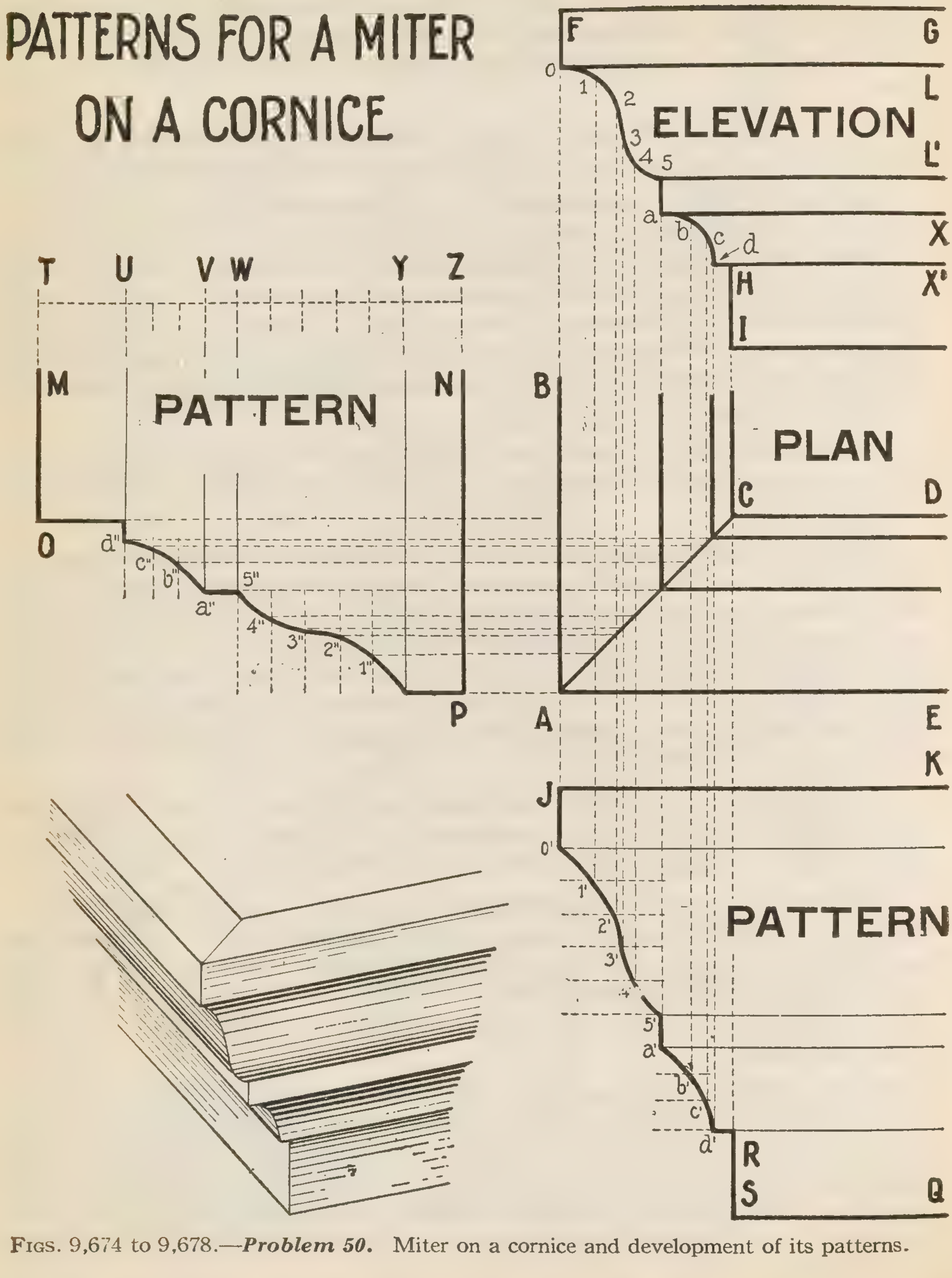
The hypotenuses of these triangles give the true lengths of the six lines that are to be used for triangulation. Now proceed to lay out the pattern F′E′I′H′V′G′.

Make E′I′, parallel and equal to JO, from plan. Draw two vertical projection lines from P and U, downward, across the desired pattern. Then, with a radius equal to the true length of line 1, from E′, as center, draw an arc intersecting the projecting line PF′, in the point F′. Then, with a radius equal to the true length of line 2, from I′, as center, draw an arc intersecting the projection line UH′, at H′. To test the result, describe an arc from E′, as center, with a radius equal to the true length of line 5, which arc should pass through the point H′.

Next, draw an arc from F′, as center, with a radius equal to the true length of line 3, which arc is intersected at the point G′, by another arc whose radius is equal to line 6, and whose center is at H′.

Now, from the newly obtained point G′, as center, with a radius equal to the length VG (of the side elevation) describe an arc which is intersected at the point V′, by an arc drawn from H′, as center, with a radius equal to line 4. This completes the pattern of the part F′E′I′H′V′G′. The lines E′H′,F′H′ and H′G′, upon this pattern indicate the direction of the slight twists required.

The face JKQP, is represented in its true shape as J′K′Q′P′. The projection lines drawn across this latter figure, from the plan, show how J′K′, is made equal to JK, and P′Q′, is made equal to PQ, the perpendicular distance between the lines J′K′ and P′Q′, marked as *ef*, is taken from the side elevation, equal to EF. This figure was laid out separately so as to make it easier to understand its derivation. It really should form a part of a



FIGS. 9,674 to 9,678.—***Problem 50.*** Miter on a cornice and development of its patterns.

larger pattern that includes the top PQMN. This larger pattern is shown at A′D′M′N′, wherein the wider end is a reproduction of the figure J′K′Q′P′, while the narrower end C′B′M′N′, is the true shape of the top face PQMN.

Projection lines drawn from the elevation show that M′N′, is equal to MN. The perpendicular distance between the lines B′C′ and M′N′, marked as *ab*, is taken from the elevation view, equal to line FG. Furthermore, the face represented in the elevation, edgewise, by the single line HI, and, in plan, as face OURL, is shown in its true shape at O′U′R′L′, wherein the line O′L′, equals OL, and line U′R′, equals UR, while the perpendicular distance, *ih*, between the lines O′L′ and U′R′, is equal to line 2. This figure too was drawn separately merely to better explain its derivation. Again, it is made a part of a larger pattern which is shown at Z′ZXX′, wherein the wider portion Y′YXX′, is a repetition of O′L′R′U′, and the narrower portion Z′ZYY′, is the true shape of the face that is represented edgewise, in the elevation, by the single line HV, and in plan, by the hidden portion URMN. Z′Z, is made equal to MN, and Y′Y, is equal to U′R′, or UR. The perpendicular distance *mn*, is equal to line 4.

It is obvious that the patterns here shown separately may be combined by the mechanic, into larger sections, to be cut out of one piece of stock, whenever that may prove desirable, as, especially, in elbows of small size. If cut separately, for large sized elbows, the different parts will have to be provided with additional strips of liberal size, for laps or locks.

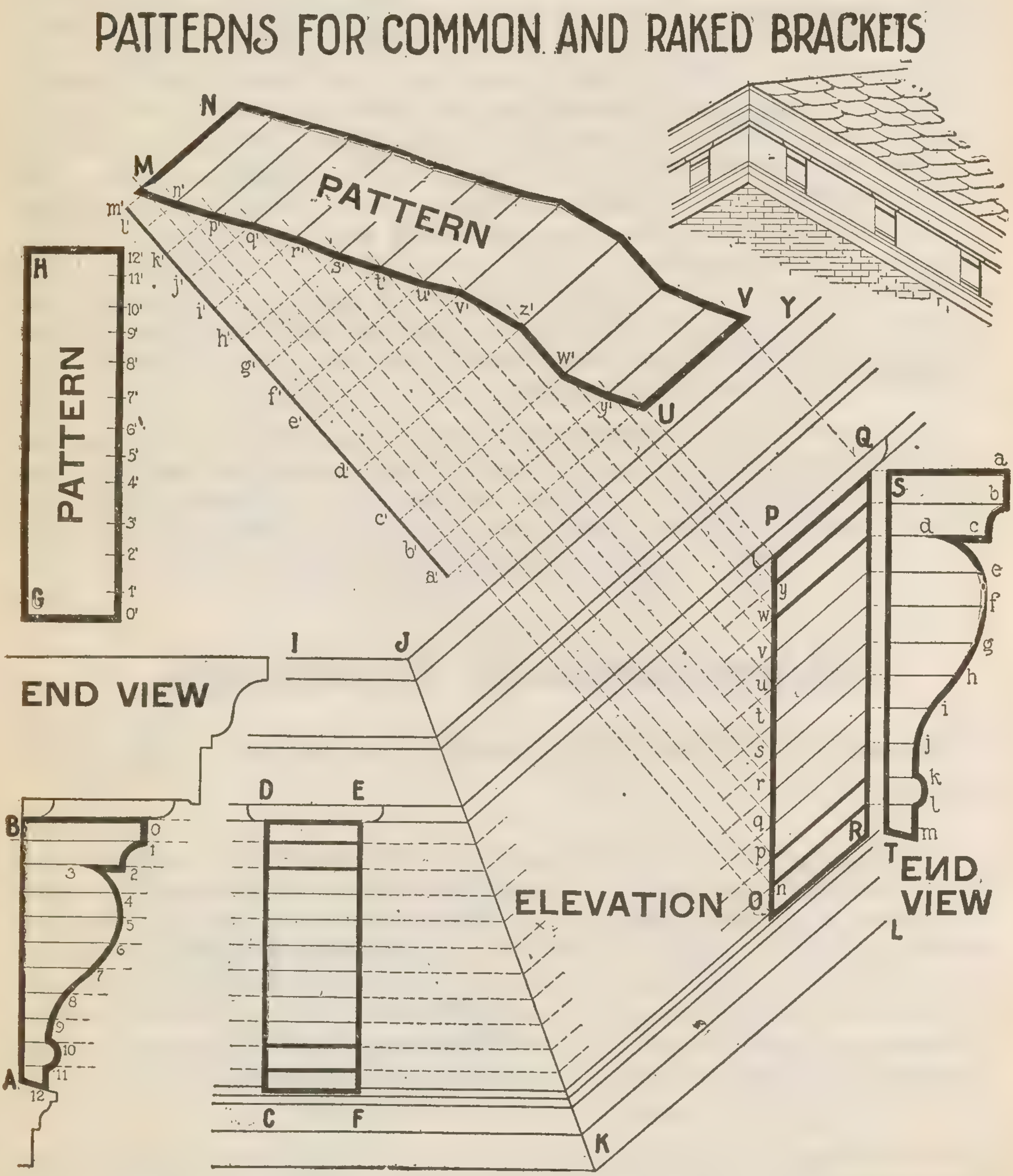
Miscellaneous Problems.

Problem 50.—Pattern for a miter on a cornice. Figs. 9,674 to 9,678.

The curved parts in the elevation of the cornice IHF, are divided into equal parts by the points 1,2,3,4,5, and *a*,*b*,*c*,*d*, from which projecting lines are drawn downward, toward *o*′,1′,2′,3′,4′,5′,′*a*,*b*′,*c*′,*d*′ and also to right, toward 1″,2″,3″,4″,5″,*a*″,*b*″,*c*″,*d*″. YZ, is made equal to F*o*′,YW, to the distance between the lines *o*L and 5L′. Then the distance WY, is divided into as many parts as there are equal parts in the curve *o*5, and from these divisions upon the line WY, vertical projection lines are drawn to meet the previously drawn horizontal projection lines in the points 1″,2″,3″,4″,5″, which define the corresponding outline of the pattern.

The distance WV, is made equal to that of 5*a*′, the distance VU, to the distance between the lines *a*X and *d*X′, and is divided into as many equal parts as are in the curve *ad*.

Vertical projection lines from the dividing points upon VU, at their intersections with the previously drawn horizontal projection lines, give the points for the corresponding part of the pattern. The line TU, is made



Figs. 9,679 to 9,684.—*Problem 51.* Common and raked brackets on a cornice and development of its patterns.

equal to HI. The other pattern QSRJK, is an exact counterpart of the first pattern.

Problem 51.—Patterns for common and raked brackets on a cornice. Figs. 9,679 to 9,684.

The common bracket is frequently used as ornament on a horizontal cornice. When such a bracket ornament is to be used on a gable cornice, it is called a raked bracket or gable bracket. The patterns for each bracket consist of two flat sides exactly shaped like the profile and of the development of the front part of the bracket that is to be bent so as to truly join to the flat sides.

In the drawing AB*o*12, represents the side view of the common bracket and CDEF, represents the front view.

The pattern for the flat sides of the bracket must be cut identically to the size and shape of the end view. To reproduce the end view, for the pattern, the curved profile is, first divided into a number of parts, preferably but not necessarily equal, in the points 1,2,3, etc., and then its surface divided by parallel lines drawn through the several points of division on the end view.

For the drawing of the pattern of the flat side, draw a straight line of the length AB, upon which set off the divisions made on it by the parallels.

Then draw these parallels and, in proper order, make these equal to the lengths of the parallels on the end view. The end points of these produced parallels are then joined by straight lines and curves, to conform with the shape in the end view. The pattern for the front of the common bracket, shown at GH12′,O′, is a rectangular strip whose width is equal to the width CF (in the elevation), and whose length is equal to the stretchout of the profile 0,1,2......12, that is, to the combined length of all the divisions from *o*, to 12, in the end view. The numbers 0′,1,2,3′, etc., of the pattern GH12′0′, correspond to 0,1,2,3, in the end view.

In the illustration, JK, is the miter line between the horizontal and the raking parts of the cornice. This miter line should be made so as to bisect the angle IJY. Only then the identically shaped horizontal and gable parts of the cornice can be made to meet each other exactly.

The raked bracket is made as wide as the common bracket in a horizontal direction, both in its elevation and end views. However, in the

direction of the gable line, the raked bracket will show a greater length than that of its horizontal width. Thus the distances PQ, and its counterpart OR, are greater than the shortest distance between the lines OP and RQ, which shortest distance, as stated, is equal to CF. The height of the raked bracket is longer than that of the common bracket since it is the oblique distance between two parallels in the cornice while the common bracket occupies the perpendicular, shortest distance between them, As to the side view of the raked bracket, while it is longer than the side view of the common bracket, since it is equal to the vertical height of the raked bracket, horizontally, in every part, it is exactly equal to the corresponding part in the common bracket. Thus S*a*, and all the parallels in the end view of the raked bracket TS*am*, are equal to the corresponding parallels upon the end view AB*o*,12.

The pattern for the flat side of the raked bracket is omitted in the drawings because it is an exact reproduction of the side view and is obtained in the same way as for the pattern for the flat side of the common bracket.

As to the pattern for the front part of the raked bracket, it has an irregularly oblique shape, shown at UVNM, whose width UV, is equal to PQ, and whose surface is made up lengthwise, of obliquely terminating parallel strips that are the variously shaped sections upon the front of the raked bracket produced by the parallels. The profile of the raked bracket is divided into a number of parts by the points *a*,*b*,*c*,. . . .*m*, which are derived from the parallels of the common bracket produced to their intersections with the miter line KJ, and from there, projected upon the front view of the raked bracket, by parallels to the roof line; thence to the edge ST, of its side view whence the projection lines run horizontally, parallel to S*a*, to the points *a*,*b*,*c*,. . . .*m*.

To plot the pattern UVNM, draw the stretchout line *a′m′*, perpendicular to the gable line JY, and lay off upon it all the distances into which the profile is divided by the parallels. Thus the combined parts of the stretchout line, *a′b′*,*b′c′*,*c′d′*, etc., will be equal to the total length of the combined parts *ab*,*bc*,*cd*, etc., of the profile in the end view. From the division points on the stretchout line, draw the lines *a′*U′,*b′y′*,*c′w′*, etc., parallel to the gable line JY. Then, from the several points of intersection of the parallels with the bracket edge PO, draw a series of projection lines at right angles to the gable line, up to the parallels drawn from the divisions of the stretched line, thus obtaining the points U,*y′*,*w′*, etc., as one of the longitudinal outlines of the pattern which is then completed by drawing the opposite longitudinal outline, VN, every part of which being drawn parallel to corresponding, parallel to the first part of UM.

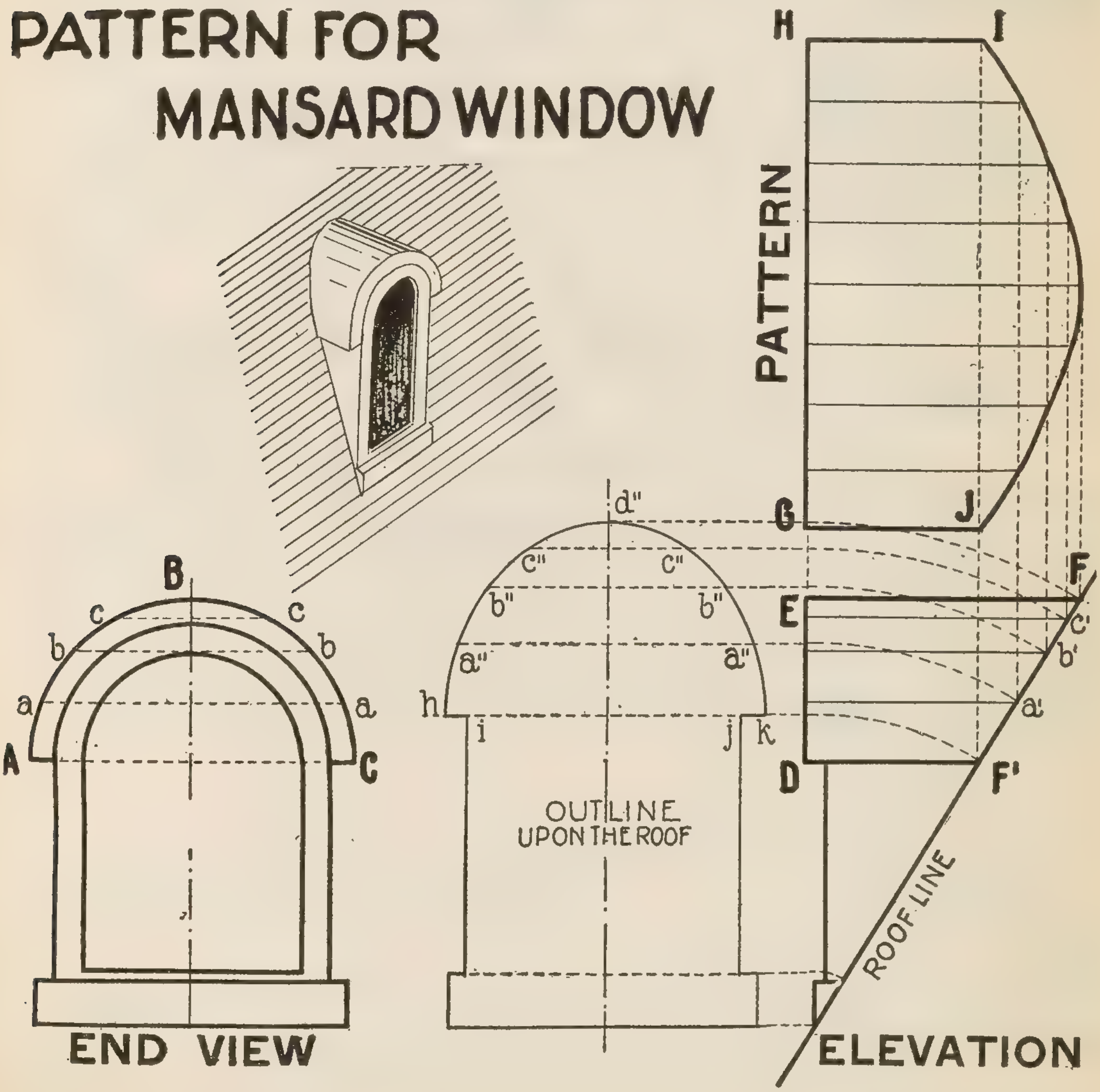
A sufficient amount of stock should be added to the patterns of the flat

side pieces for required laps. Along the curved parts of the outline, the laps will have to be notched to facilitate bending.

The smaller the radius of a curve, the closer the notches should be placed, along the outline of the pattern.

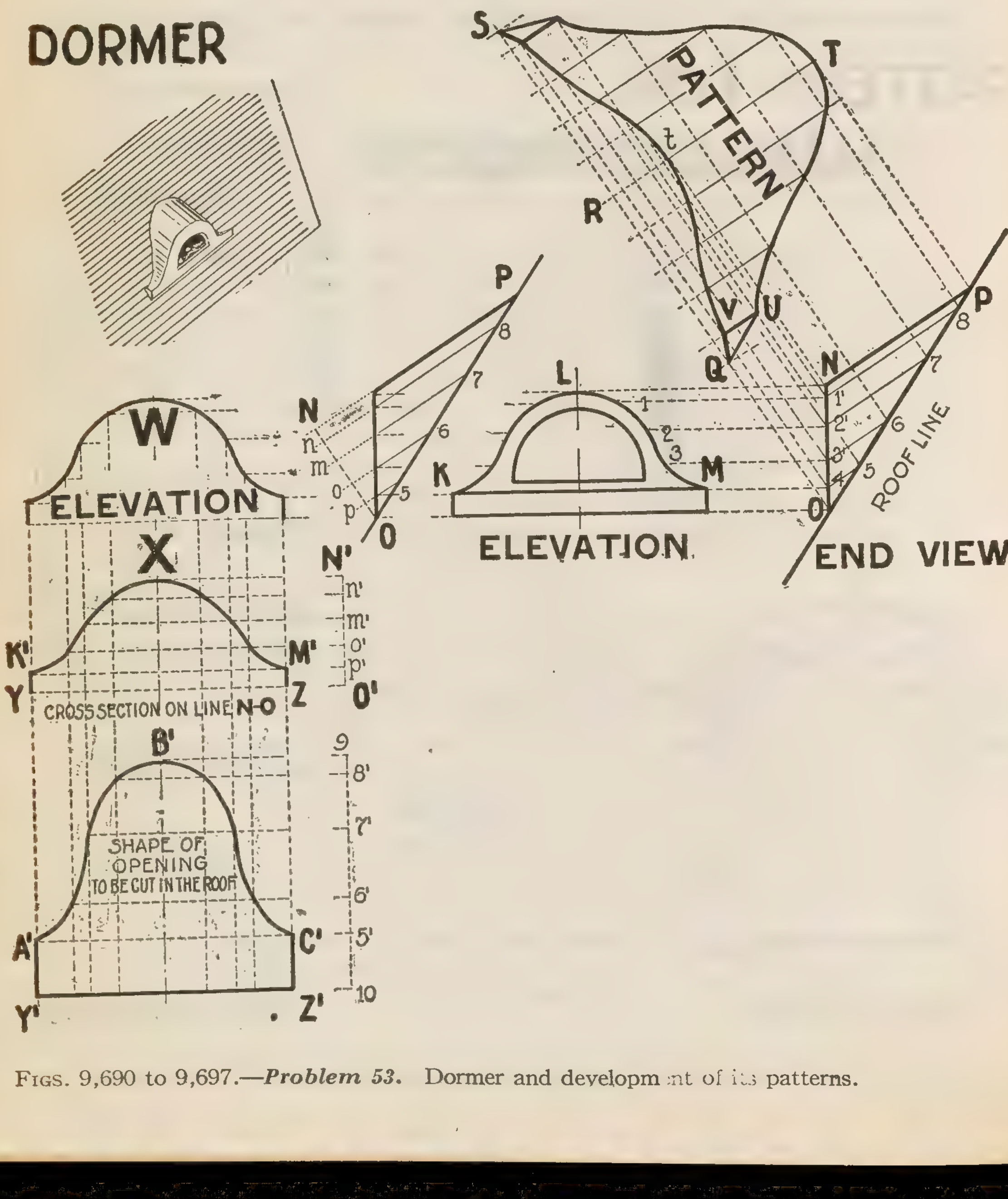
Problem 52.—Pattern for mansard window. Figs. 9,685 to 9,689.

The circumference of the hood ABC, is divided into a number of equal



Figs. 9,685 to 9,689.—*Problem 52.* Mansard window and development of its patterns.

parts, by points *a,b,c*, etc., which are projected to the points F′,*a*′,*b*′, etc., upon the roof line. The pattern GHIJ, is obtained like the development of a cylinder. The line GH, is equal to the total length of all the divisions in the semi-circumference ABC. If it be required to plot the outline upon the roof where the window booth is joined to the roof, it may be obtained by arcs drawn from the points F′,*a*′,*b*′, etc., which locate the distance between the parallels *hk*,*a″a″*,*b″b″*, etc. The distance *hk*, is equal to AC, and *a″a″*, to *aa*, etc.



FIGS. 9,690 to 9,697.—***Problem 53.*** Dormer and development of its patterns.

The other parts of this outline are too obviously derived to call for an explanation.

Problem 53.—Pattern for dormer. Figs. 9,690 to 9,697.

The hood over the dormer is developed after the manner used for the pattern of the slope sheet of a boiler. Here, KLM, in the elevation is divided into a number of equal parts in the points 1,2,3, etc., which are projected to the edge ON, of the end view, obtaining points 1′2′3′, etc. Thence, the lines 1′8,2′7, etc., are drawn parallel to the line NP. Now the true profile of the rounded hood of the dormer has to be laid out. For this, on the reproduced end view, to the left of the elevation, the line NP, and all the parallels to it are extended outward, just as if the hood itself were enlarged forward. The extended hood is then cut by line NO, at right angles to NP, and intersecting the oblique parallels in the points *m,n,o,p*. At W, is shown an exact reproduction of the outline of the elevation. Beneath this, at X, is the cross section on the line NO.

Its defining points, as is plain from the drawing, are derived from the intersection of the vertical projection lines (from the dividing points upon the circular edge of the elevation) with the horizontal projection lines coming from the points N′*n*′M′*o*′*p*′O′, which are exactly equal to the corresponding distances on the cutting line NO.

Now, to plot the pattern for the hood of the dormer, a stretchout OQS, is drawn at a right angle to NP, which line is crossed at *t*, by a line RT, perpendicular to it (hence parallel to NP). To either side of the line RT, which is intended as a center line for the pattern, set off upon SQ, the divisions which the defining points made upon the profile of the cross section YK′M′Z, in proper order, so that the central division X, should fall upon R, and the extreme divisions Y and Z to fall upon S and Q respectively.

From the divisions thus obtained on the stretchout line, perpendiculars are erected across the desired pattern.

These perpendiculars being cut by the projecting lines which start from the points P,8,7, etc. (in the end view), give the defining points of the pattern, which is then completed by the additions of the triangle QVU, and the one at S, to represent the little triangle 045, of the side view.

The shape of the opening to be cut in the roof for the dormer is plotted by means of vertical projection lines from the cross section and the horizontal lines which are drawn from the points 9,8′,7′, etc., which are equal to the corresponding lengths P8,87,76, etc., upon the roof line.

CHAPTER 149

Boiler Plate Work

The term *plate* as distinguished from *sheet* refers to material having a thickness greater than No. 12 U. S. gauge.

For boiler work, according to the A. S. M. E. Boiler Code, which is the standard for first class boiler construction: "The minimum thickness of any boiler plate under pressure shall be ¼ inch." Thus the thinnest boiler plate is considerably thicker than the heaviest sheet metal, and in laying out allowance must be made for distortion of the metal in bending, as will later be explained.

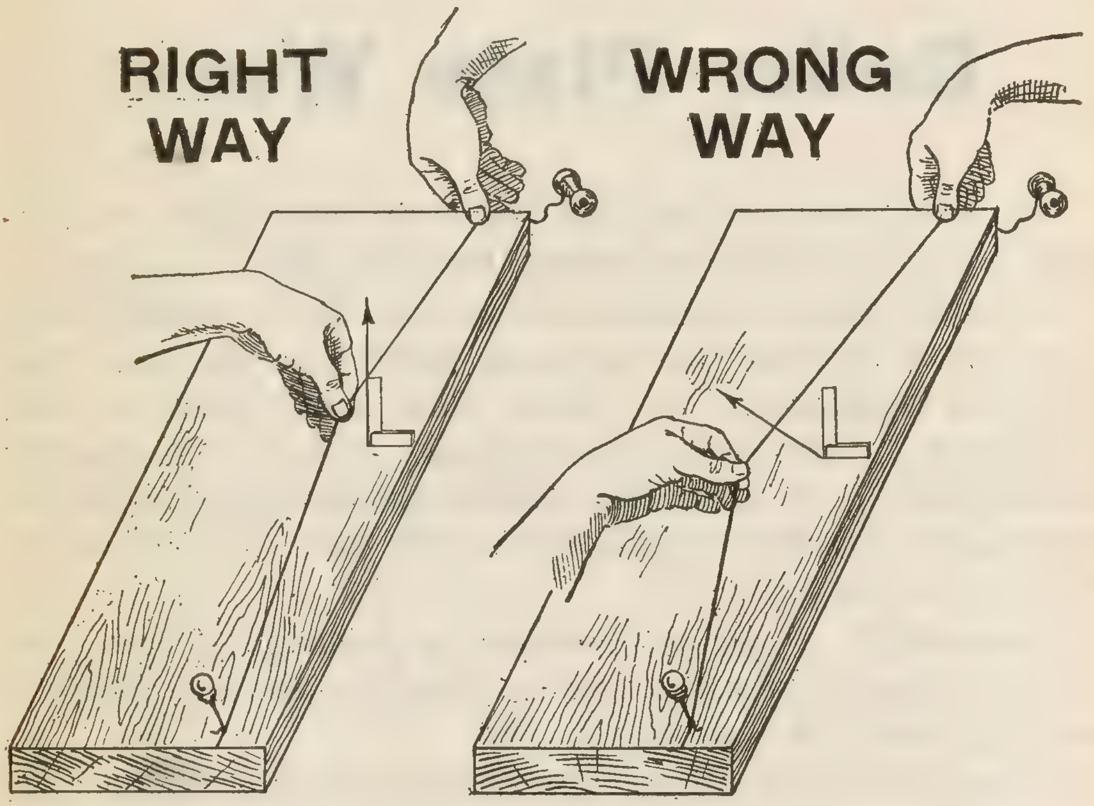
The work of laying out consists in developing from blue prints or drawings the true size and shape of the boiler plates, locating center for rivet holes, etc.

The methods of development have already been explained and the development may be a pattern, or it may be laid out directly on the sheet.

The work is simply an application of mechanical drawings and differs from it in that the drawing is executed full size and often upon the boiler plates instead of paper.

The layer out must work with precision and understand how to construct ordinary geometrical figures and how to develop surfaces. This is necessary because the blue prints show only the dimensions of the completed article. He must know also how the plate will react when it is being bent, forged, flanged, etc., for in some instances the metal will be upset or compressed and in others it will be expanded.

Allowances must be made for these losses and gains in length when the plate is laid out, and while, in certain cases, rules can be given which cover these allowances, it is sometimes necessary to depend upon experience. In this respect a practical boiler maker has a great advantage as he more readily understands when such allowances should be made and to what degree.



FIGS. 9,698 and 9,699.—Right and wrong way to use the chalk line. ***In pulling up the line always pull it up in a direction at right angles with the board.*** or plate—***not to one side***

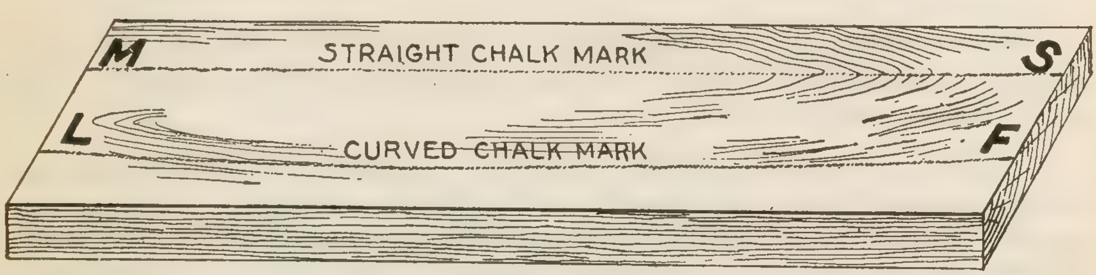
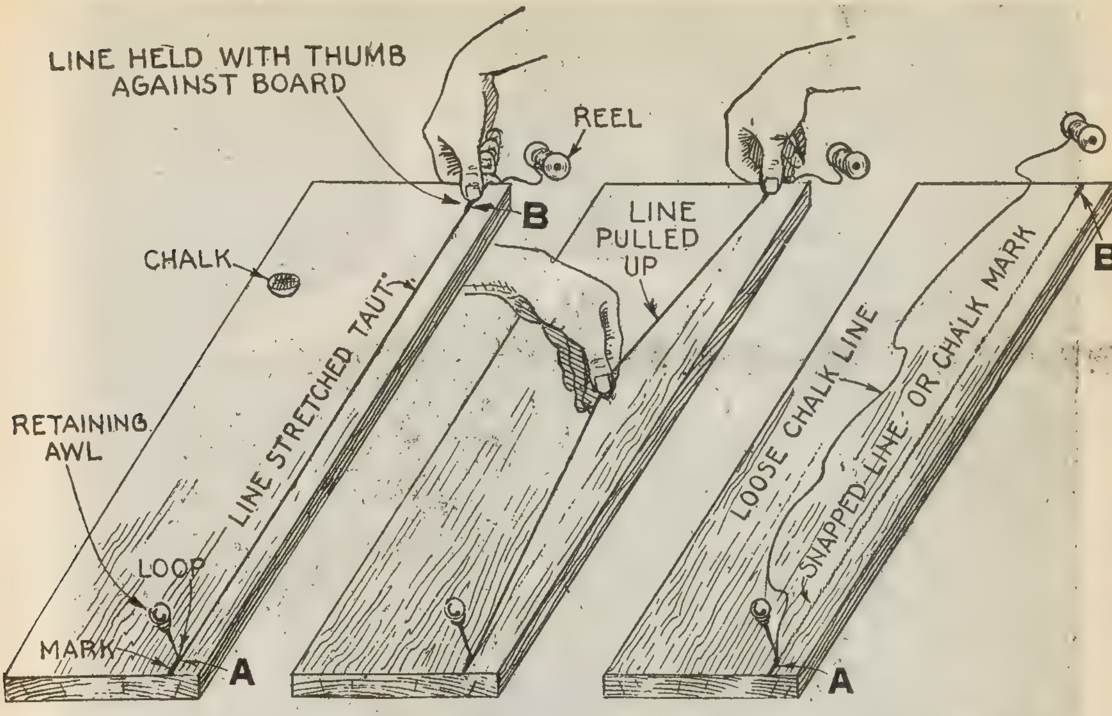


FIG. 9,700.—Chalk marks obtained by right and wrong methods of using the chalk line. When the line is pulled straight up, as in fig. 9,698, a straight chalk mark MS, will be obtained, but when pulled up to one side (as in fig. 9,699) a curved line LF, will be obtained.



FIGS. 9,701 to 9,703.—Method of using the chalk line. Mark the ends of the board as at A and B, the points between which it is desired to obtain a straight line. Insert retaining awl through loop at end of chalk line (after rubbing the chalk line with chalk) and into board through mark A. Pull line and hold taut over mark B, by thumb and second finger, pressing it down firmly on the board. Pull up line with other hand as in fig. 9,702 and let go. When the line is removed as in fig. 9,703 a well-defined chalk mark will be seen between the points A and B.

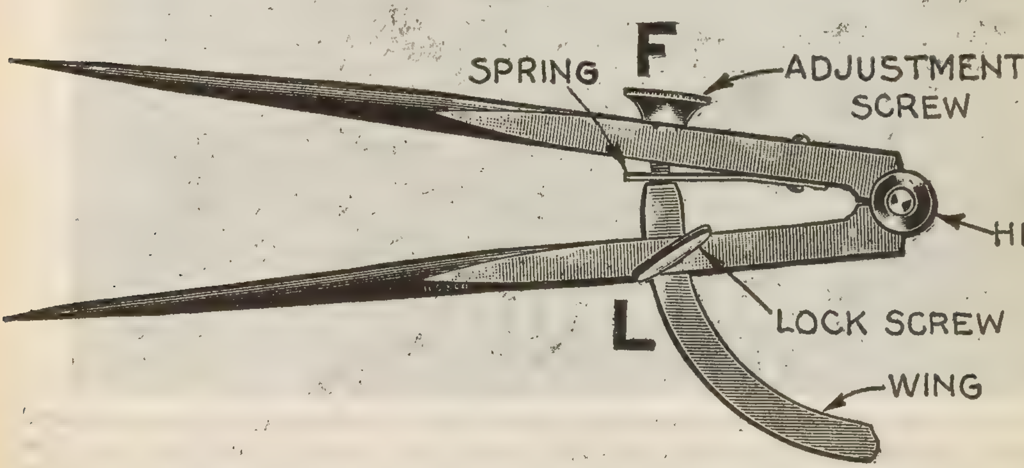


FIG. 9,704.—Winged dividers for describing and dividing arcs and circles. Evidently when the dividers are locked to the approximate setting by lock screw L, the tool can be set with precision to the exact dimension by turning adjustment screw F, against which the leg is always firmly held by the spring which prevents any lost motion.

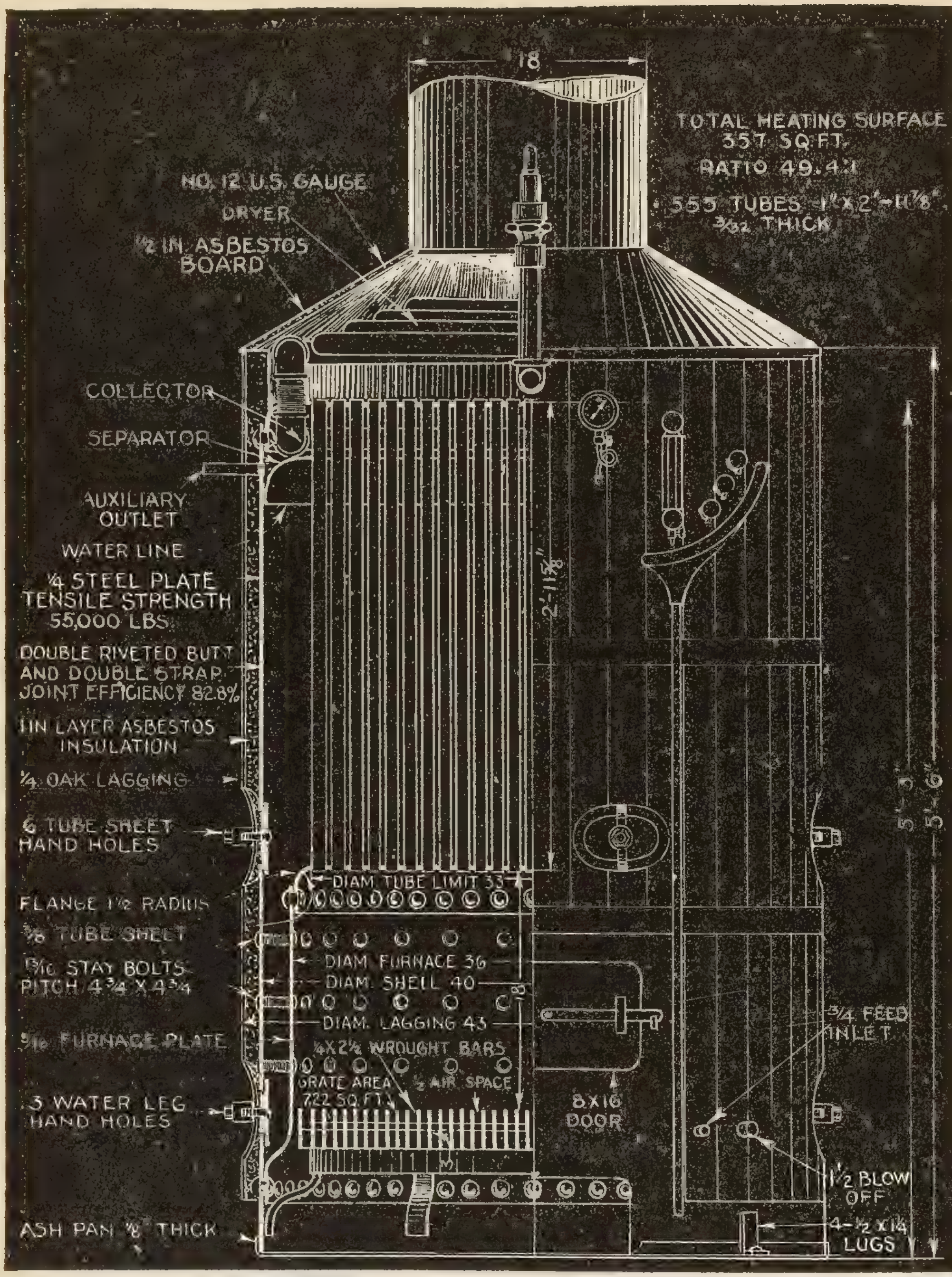


FIG. 9,705.—***Graham through tube vertical marine boiler.*** Sectional view showing principal dimensions, separator, collector and dryer, light weight built up grates, covering, etc. The oak lagging secured by metal bands makes a neat covering, though Russia iron could be used instead. ***The aim of the author*** in designing this boiler was to avoid the faults of the ordinary vertical boiler, such as inadequate heating surface, large space required and excessive weight for power developed. Capacity about 2½ times that of the ordinary boiler Designed strictly in accordance with the requirements of the ***A. S. M. E., Boiler Code.***

Ordinarily lines are drawn with chalk or soapstone pencils. Long lines are snapped in with a chalk line, short ones are drawn with a straight edge. Circles or arcs are described with trammels or as generally called "trams." Centers for rivet holes are spaced off with dividers.

When great precision is required, the surface should be chalked and a scriber and straight edge used in drawing lines. Measurements along straight lines can be made with an ordinary rule or steel tape. The approved method of measuring a curve is with a measuring wheel. The various tools just mentioned are shown in the accompanying illustrations.

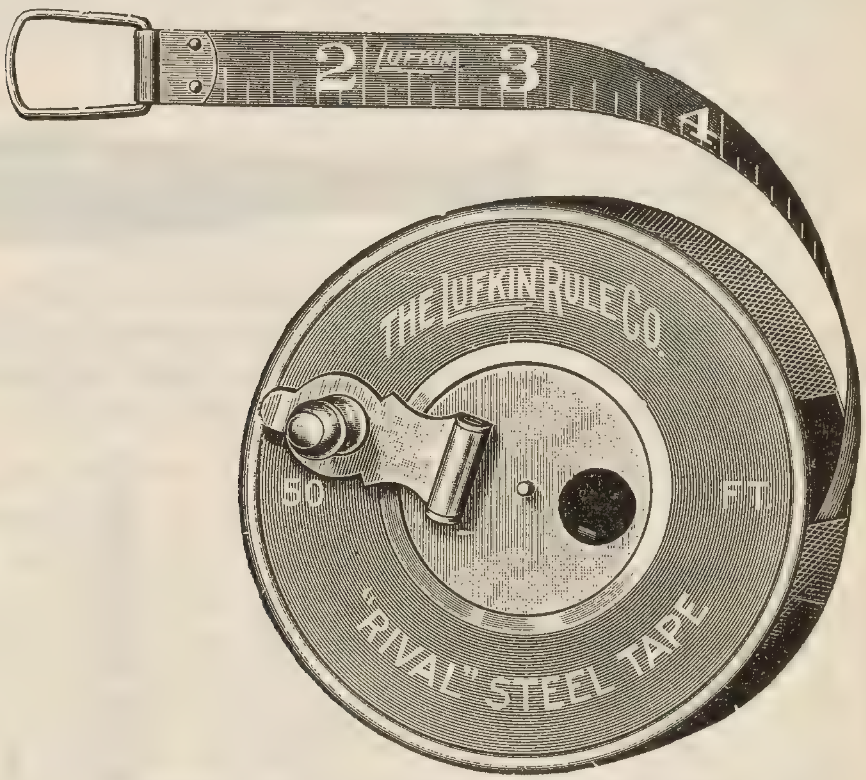
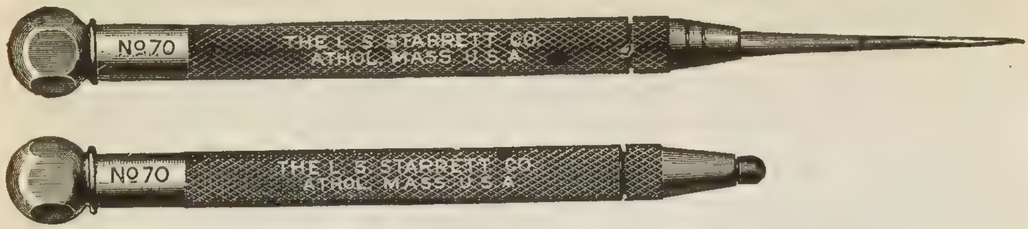


FIG. 9,706.—Lufkin "Rival" steel measuring tape, folding flush handle, opened by pressing pin on opposite side. Cases have knurled edges, which afford a firm hold when winding in tape.

Figs. 9,698 to 9,703, show use of chalk lines as practiced by mechanics, illustrating the proper method of using to avoid errors.

To illustrate the method of laying out a boiler the author has taken for an example his ***Through Tube Vertical Marine Boiler***



Figs. 9,707 and 9,708.—Starrett pocket scriber, showing scriber in open and closed positions. The stock or handle is made from steel tubing knurled and nickel plated. The scriber blade is of steel, tempered, and is held by a knurled chuck. The scriber is reversible, telescoping into the stock and is held by a slight turn of the chuck so that the point is protected inside the stock when not in use as in fig. 9,708.

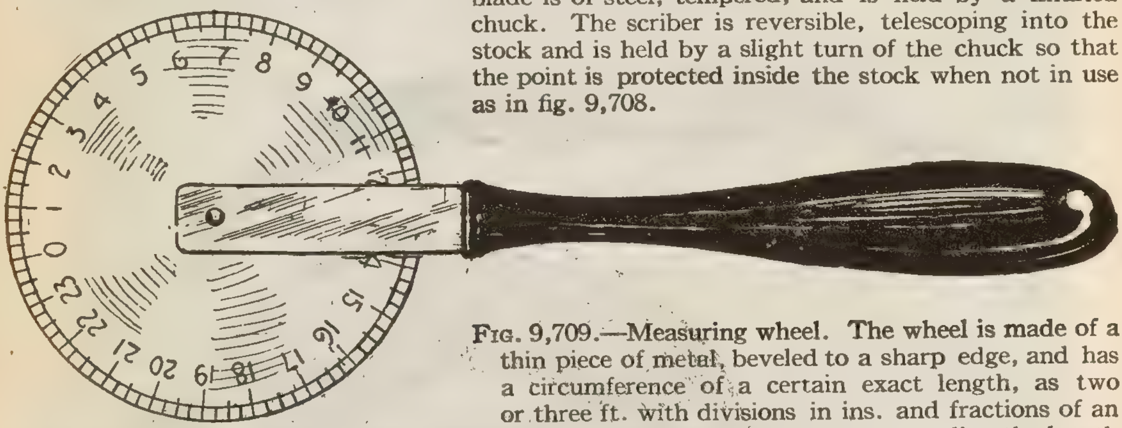
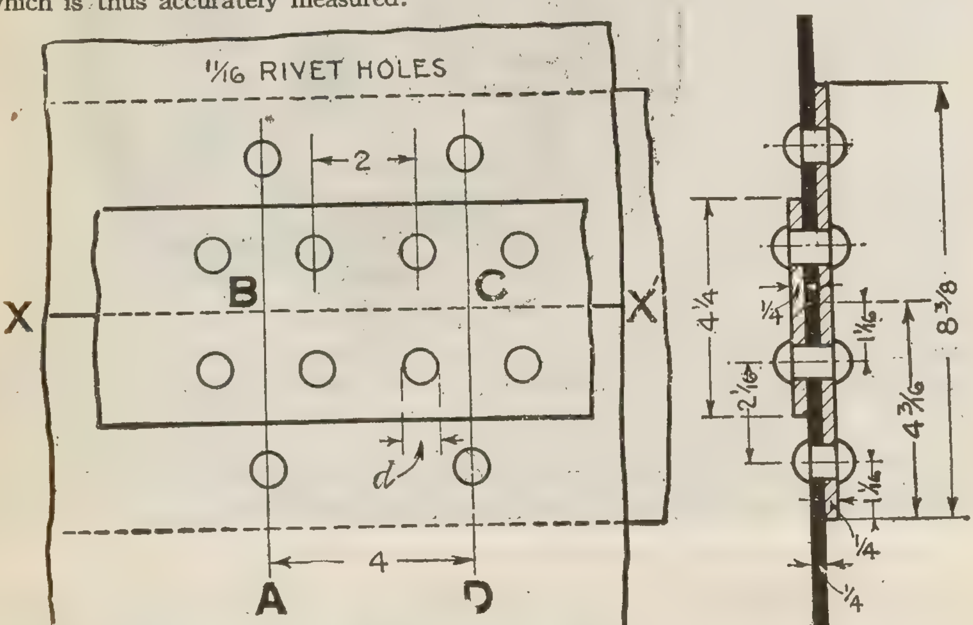


Fig. 9,709.—Measuring wheel. The wheel is made of a thin piece of metal, beveled to a sharp edge, and has a circumference of a certain exact length, as two or three ft. with divisions in ins. and fractions of an in. marked upon it. The wheel is pivoted to a handle and can be run over a line the length of which is thus accurately measured.



Figs. 9,710 and 9,711.—Butt and double strap double riveted longitudinal joint showing dimensions as obtained from the ***A. S. M. E. Boiler Code*** and those selected. Straps and plate each ¼ in. thick.

as designed in Chapter 71 of Audel's Engineers and Mechanics Guide No. 6.*

The general proportions of this boiler are shown in fig. 9,705. These dimensions will be followed as closely as possible, subject to slight modification if necessary to maintain the spacing of rivets as calculated in the design. For the longitudinal joint, the butt and double strap double riveted form is used as shown in figs. 9,710 and 9,711.

In regard to the tube sheet circumferential seams, since a considerable portion of the load coming on the tube sheets is carried by the tubes, and the area reduced by the tube holes the circumferential seam need not be so strong as the longitudinal seam. In fact, owing to the great multiplicity of tubes, the holding power of the tubes is considerably in excess of the total load that would come on the tube sheet even if the latter were solid, hence the only duty performed by the rivets of the circumferential seams is to secure a tight joint. For these seams, the maximum pitch of rivets as prescribed by the U. S. Marine Rules is 1.95 ins., however in this special case, a slightly larger pitch can be safely used.

The layout will be based upon

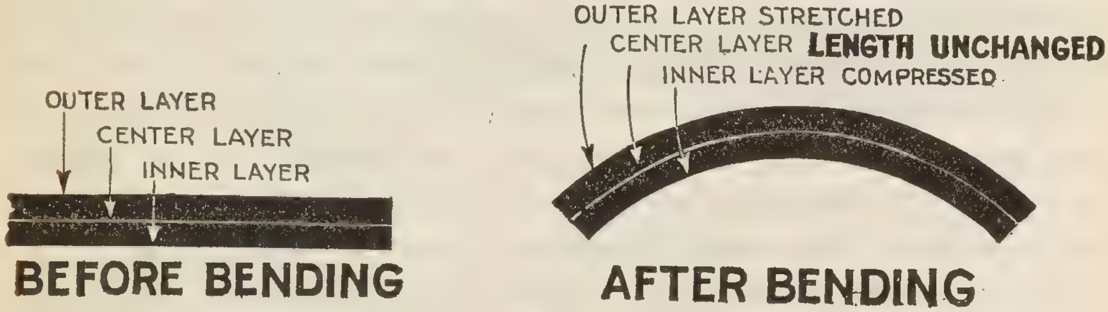
1. Longitudinal riveting proportioned as in figs. 9,710 and 9,711.
2. Circumferential riveting of not over 2⅛ ins. pitch.*

Shell Plate.—Owing to the small size of the boiler, its entire shell can be made from one plate and since the longitudinal seam is of the butt type there is no lap at the joint and accordingly the length of plate as calculated for the diameter need not be increased as with lap joints. However, the

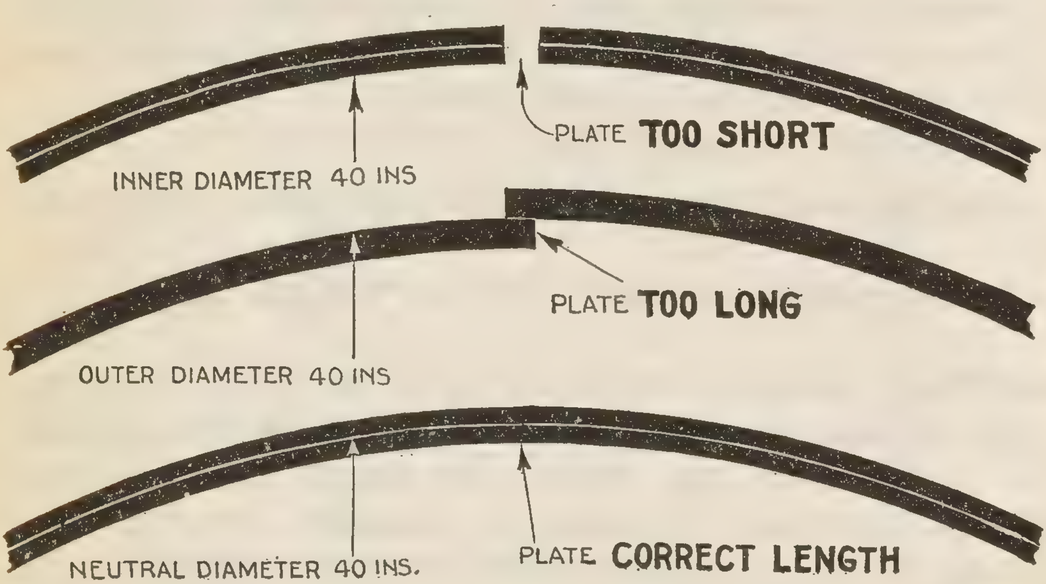
*NOTE.—For all the details of this boiler see the above mentioned Guide.

thickness of the plate must be considered, because when it is bent to the circular form of the boiler, the metal is *upset;* that is, whereas the outer layer is stretched, and the inner layer compressed, the center layer does not change its length.

Now, the diameter of the boiler as given in fig. 9,705 is 40 ins. which is the *inside* diameter, that is, the diameter of the inner layer of the plate. If this diameter be taken in calculating the length of the plate, the latter would be *too short*, because the inner layer is compressed in bending as in fig. 9,713. Again, if the outer diameter be taken (that is, inner diam. + 2 × thickness of plate) the plate would be *too long*, because the outer layer is stretched.



FIGS. 9,712 and 9,713.—Boiler shell plate ***before*** and ***after*** bending showing how the metal is upset by the bending operation.



FIGS. 9,714 to 9,716.—Effect on plate length by calculating with inner, outer and neutral diameters.

Evidently from the figure, since the length of the center layer does not change during the bending operation, the diameter of the center layer should be used in calculating the length of plate; this is known as the *neutral diameter*. As shown in fig. 9,717.

The first step in calculating the length of the shell is to find the neutral diameter.

Evidently from fig. 9,717

neutral diameter = inside diameter $\times$ ½*d* + ½*d*.
= inside diameter + thickness of shell.

Since, in fig. 9,705, inside diameter = 40 ins., and thickness of shell = ¼ ins.,

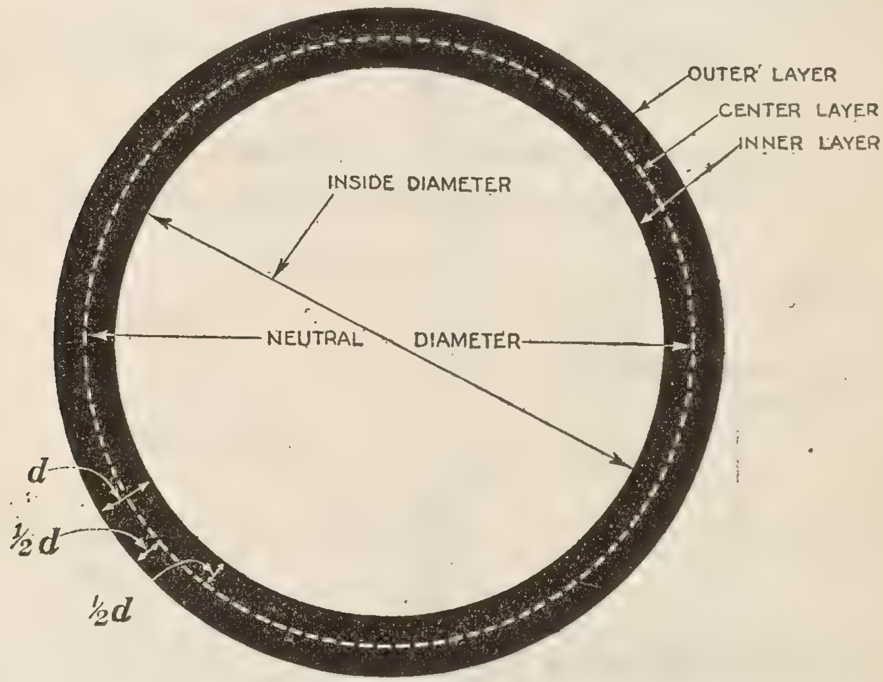


FIG. 9,717.—Cross section of boiler shell showing neutral diameter. For clearness the thickness of the shell is considerably exaggerated.

neutral diameter = 40 + ¼ = 40¼ ins.,

and since the circumference of a circle is 3.1416 times its diameter,
calculated length of shell = 40.25 $\times$ 3.1416 = 126.45 ins.

This length is subject to slight change if necessary to avoid uneven spacing of the circumferential seam rivets.

Taking 2⅛ in. pitch for the circumferential seam rivets (the same as between the two inner rows in the longtiduianl seam),

$$\text{number of circumferential rivets} = 126.45 \div 2\tfrac{1}{8} = 59.5.$$

Since there cannot be a fractional number of rivets, make number of circumferential rivets = 60. To accommodate this number of rivets having $2\frac{1}{8}$ in. pitch, the length of shell must be changed, that is,

$$\text{modified shell length} = 60 \times 2\tfrac{1}{8} = 127.5 \text{ ins.}$$

Use this value in laying out the plate.

The lines to be laid out on the plate are shown in fig. 9,718; they may be laid out as follows:

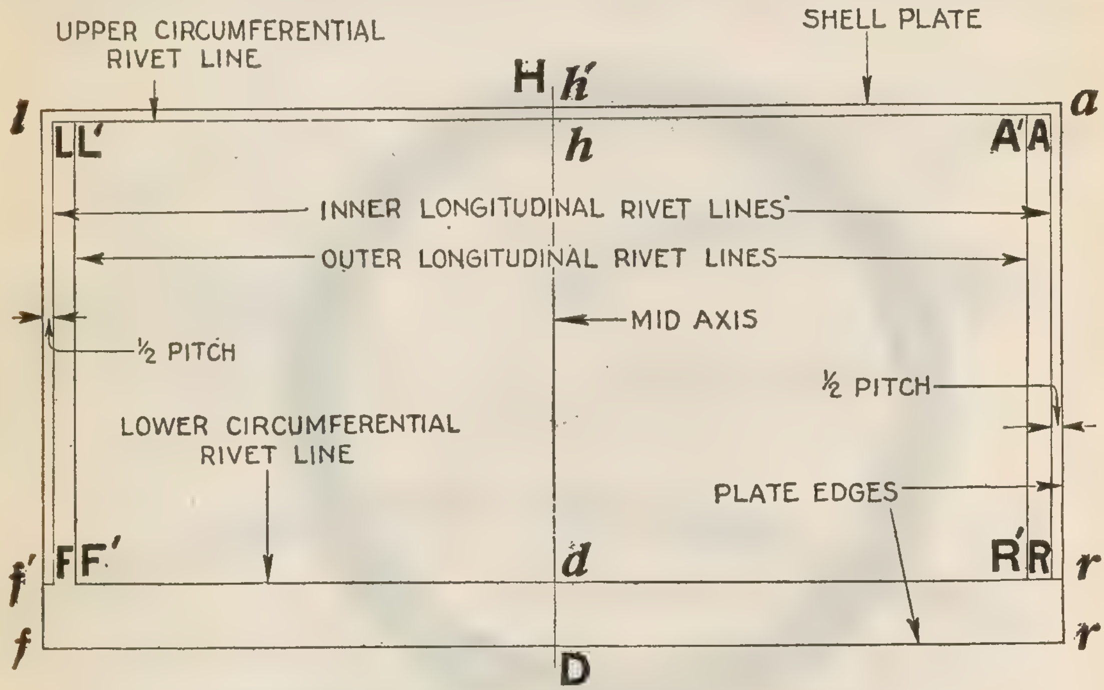


Fig. 9,718.—Boiler shell plate showing lines to be laid out.

1. Lay out lower circumferential rivet line.
2. Lay out mid axis.
3. Lay out longitudinal rivet lines.
4. Lay out upper circumferential rivet lines.
5. Lay out plate edges.
6. Lay out spacing for rivets.

Lower Circumferential Rivet Line.—In the design as

modified, the lower circumferential rivet line is $7\frac{1}{8}$ ins. above the lower edge of the plate.

Accordingly in fig. 9,718 assuming the lower plate edge *fr*, to be planed true, lay off *ff'* and *rr'*, each = $7\frac{1}{8}$ ins. and draw *f'r'*, which is the lower circumferential rivet line.

Locate the point *d*, midway between the ends of the plate. The modified shell length being 127.5 ins., lay off half of this length less $1^{1}/_{16}$ or

$$(127.5 \div 2) - 1^{1}/_{16} = 62^{11}/_{16}$$

on each side of *d*, giving the points F and R, which are points through which the inner longitudinal rivet lines pass.

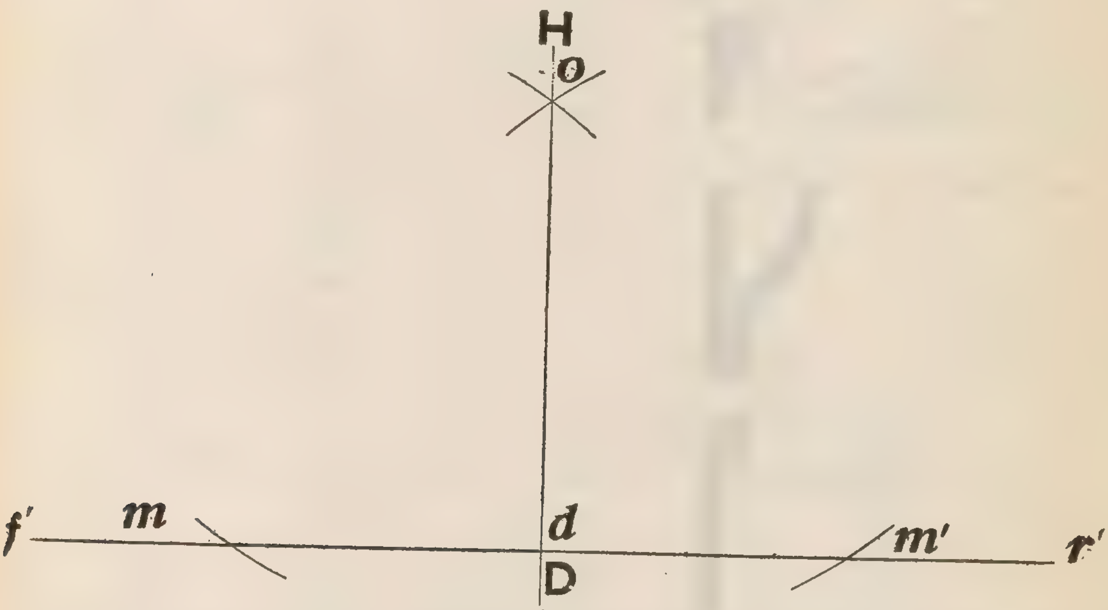


FIG. 9,719.—Method of erecting the perpendicular mid axis with precision. Through *d*, as center with any radius describe arcs cutting the lower rivet line *f'r'*, at *m* and *m'*. Through *m* and *m'*, as centers with the same radius describe arcs intersecting at *o*. Through *d* and *o*, draw the mid-axis DH, which will be perpendicular to *f'r'*. A perpendicular thus erected will be nearer correct than when drawn with a straight edge and T square. In the above method, the length of the radius should be just a little less than the width of the plate.

The rivet lines which come near the plate edges should be located at such distance from the edges of the plate, that the plate will have proper strength against shearing between rivet and edge of the plate. This distance has been found by experience such as will give about one rivet diameter of solid metal, that is $1\frac{1}{2}$ rivet diameters from edge of plate to center of rivet hole.

The diameter of the rivets after driving being $^{11}/_{16}$ in., the distance from rivet line to edge of plate should be not less than

$$^{11}/_{16} \times 1\tfrac{1}{2} = {}^{33}/_{32} = 1^{1}/_{32} \text{ ins.}$$

The dimensions for the longitudinal joint as designed are shown in figs. 9,710 and 9,711, which show the distance from inner rivet centers to edge of plate to be $1\ ^1/_{16}$ in.

Accordingly in fig. 9,718 lay off on the lower rivet line a distance $= 1\ ^1/_{16}$ in. from point F and R, giving point f' and r', through which, lines representing the longitudinal edges of the plate pass.

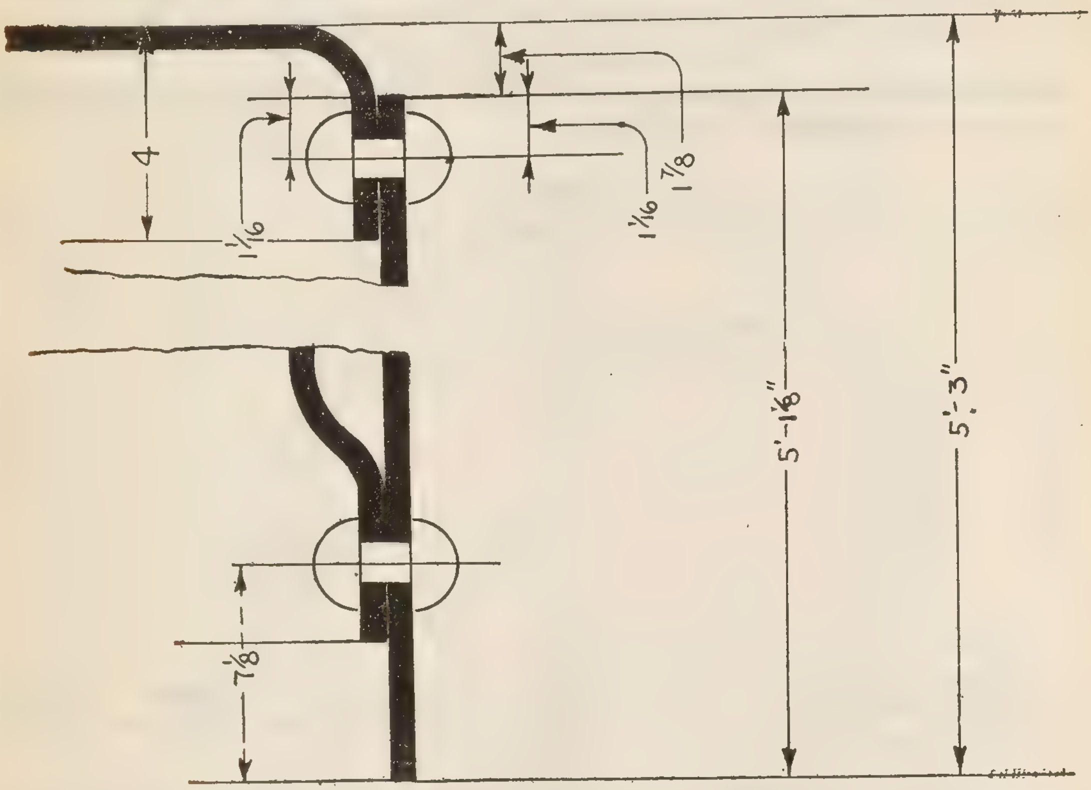


FIG. 9,720.—Detail of shell and upper and lower circumferential riveting for finding distance between lower and upper circumferential rivet lines In order to illustrate clearly the dimensions, the detail is ***not drawn to scale.***

Mid-Axis.—Through the point *d*, in fig. 9,719, which is midway between the longitudinal edges of the plate, erect the mid axis DH, perpendicular to f′r′.

This perpendicular must be erected with precision by the method shown in fig. 9,719.

Longitudinal Rivet Lines.—First find the distance between the lower and upper circumferential rivet lines.

In the general view of the boiler fig. 9,705, the length from lower edge to top of upper tube sheet is 5′-3″. Since the tube sheet projects above the top edge of the plate it is necessary to allow for this.

In the detail view fig. 9,720 the height of shell, that is width of plate, is 5′-1⅛″, or 61⅛ ins. and height of lower circumferential rivet line, 7⅛ ins., from which distance between upper and lower rivet lines is

$$61\tfrac{1}{8} - 7\tfrac{1}{8} = 54 \text{ ins.}$$

This distance permits uniform spacing of the rivets with 2 in. pitch. In fig. 9,721, lay off on the mid axis, HD, the distance *hd* = 54 ins. Set compasses to this distance and with *h*, as center, describe arcs *m* and *m′*.

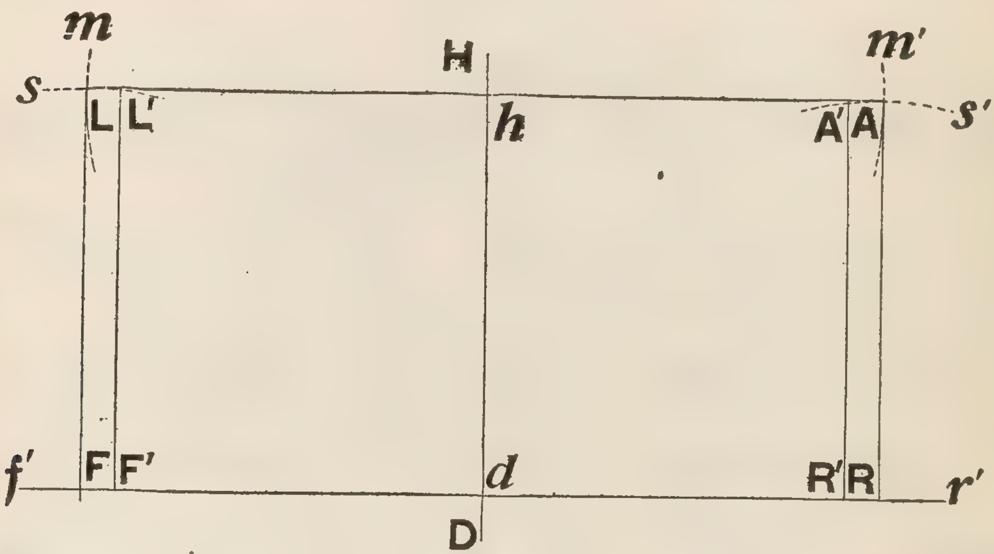


FIG. 9,721.—Method of laying out the longitudinal rivet lines.

Also, with F and R, as centers describe arcs *s* and *s′*. The intersections of these arcs give points at the extremities of the inner longitudinal rivet lines. Hence connect these points with F and R, giving *inner* longitudinal rivet lines LF and AR.

The *outer* longitudinal lines L′F′ and A′R′, are laid out parallel to LF, and AR, as shown in fig. 9,721, spaced a distance of 2 $^{1}/_{16}$ ins.

Upper Circumferential Rivet Line.—This is drawn by simply connecting *h*, with the points L′ and A′, in fig. 9,721, giving the straight line L′A′, since L′, and A′, are at equi-distances from FR.

Plate Edge Lines.—Through points *f* and *r′*, in fig. 9,718 erect perpendiculars to *fr*, and through *h′*, located at a distance of 1$\frac{1}{16}$ in. from *h*, draw *la*, parallel to LA, giving the three edge lines *fl*, *la*, and *ar*, which with the original edge *fr*, defines the outlines of the plate.

Unless the boiler be designed for a stock size plate, the latter must be machined to size.

Layout for Rivets.—The various lines as laid out are shown

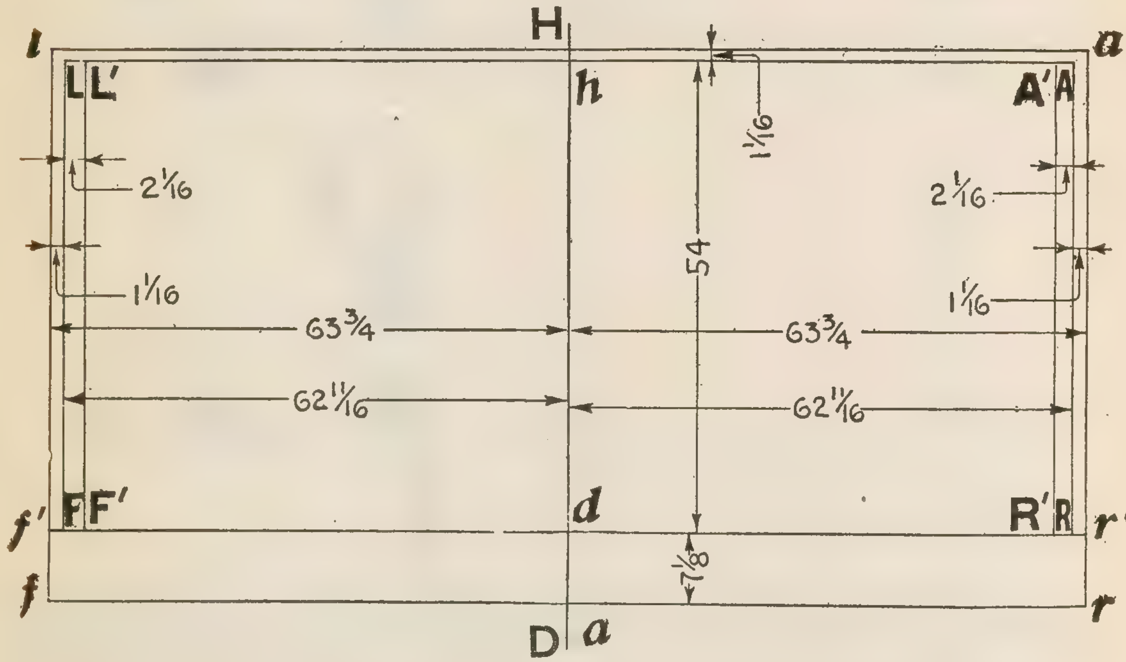


FIG. 9,722.—Lines of the shell layout with dimensions illustrating the spacing of rivets.

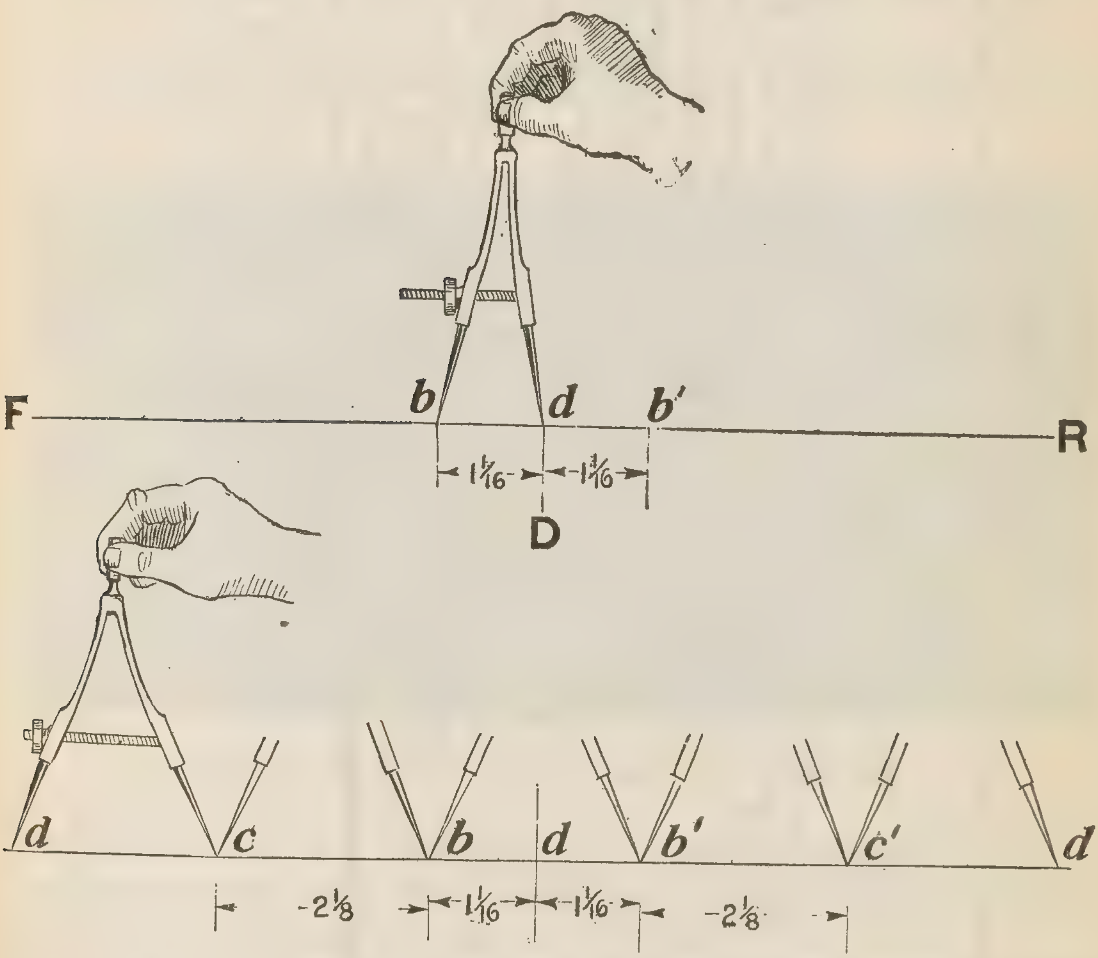
in fig. 9,722. Here, the dimensions are given to illustrate spacing of the rivets.

The length of the lower circumferential seam *f′r′*, is 127.5 ins. and for the selected pitch 2$\frac{1}{8}$ ins.

$$\text{number of rivet holes} = 127.5 \div 2\tfrac{1}{8} = 60$$

as previously calculated.

There being an even number of rivets, half of them will lie on each side of the mid axis HD; that is, point *d*, where mid axis intersects the rivet line will be midway between two rivets. Hence, having accurately laid out the rivet line *f′a′*, so that *df′* = *dr′* = 63¾ ins., set dividers to half the pitch, or 1$\frac{1}{16}$ ins., and with *d*, as center in fig. 9,723 describe arcs cutting the rivet line at *b* and *b′*. If dividers be correctly set, the distance *bb′*, should equal the pitch or 2⅛ ins. Now, set dividers to distance *bb′*, and space off



FIGS. 9,723 and 9,724.—Setting of dividers and trial spacing for rivet centers on the lower circumferential seam.

bc, *cd*, etc. If the setting be correct, there should be 30 points from *b*, to F; if not, adjust dividers with hair spring screw, and respace until the last division coincides with F. With the correct setting finally obtained, space off similar points, from *b′*, to R, the complete layout appearing as in fig. 9,725.

For the inner longitudinal seams LF and AR, the pitch from fig. 9,710.

FIG. 9,725.—Rivet centers as spaced in the lower circumferential rivet seam.

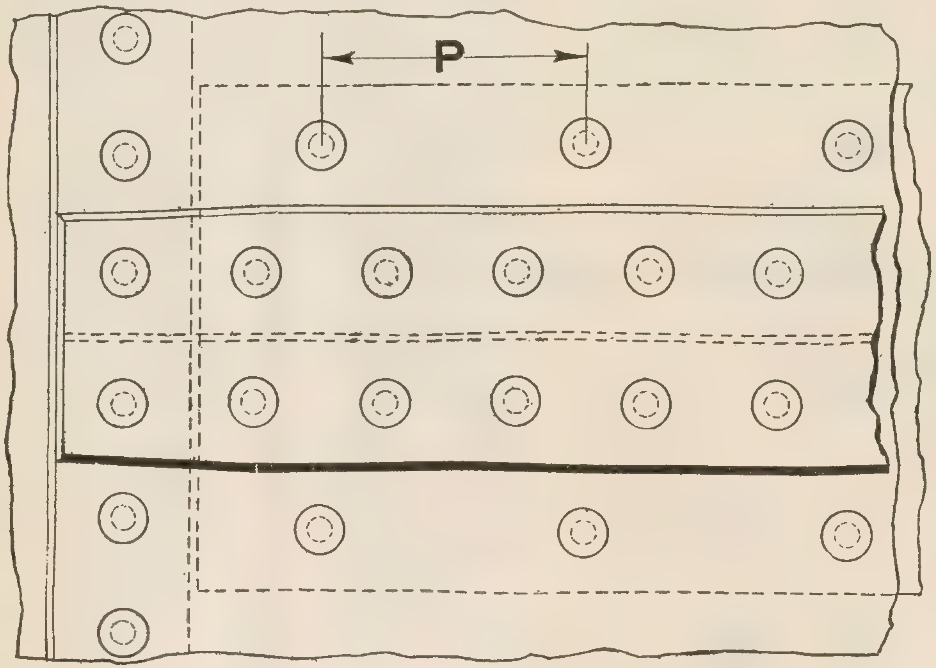


FIG. 9,726.—Example of butt and double strap joint, double riveted.

is 2 ins. and the length of seams, from fig. 9,722 is 54 ins. Accordingly for each seam,

number of rivets = $(54 \div 2) + 1 = 28$

The first and last rivet of these seams lie on the circumferential rivet lines, and so at each intersection of the rivet lines there will be one rivet in common; this is shown for one end in fig. 9,726.

For the outer longitudinal seams L′F′ and A′R′, fig. 9,722, the pitch, as shown in fig. 9,726 is 4 ins. and here it will be noted that the last rivet is at a distance of 1½ times the pitch from the circumferential rivet line, hence length outer longitudinal rivet lines

$= 54 - (1\frac{1}{2} \times 2)\,2 = 54 - 6 = 48$ ins.,

and for 4 in. pitch.,

number of rivets = $(48 \div 4) + 1 = 13$

*NOTE.—***The reason*** for adding one rivet is because there is a rivet at F, at the beginning of the line.

for the 54 in. seam. The spacing then will be

Length of seam	54 ins.
space for 13 rivets: $13 \times 4 =$	52 ins.
Leaving	2 ins.

that is the end rivets will be located 1 in. from the end of the seam.

The complete rivet layout for the shell will appear as in fig. 9,727.

Layout for Tube Sheet Hand Holes.—In fig. 9,705 six tube

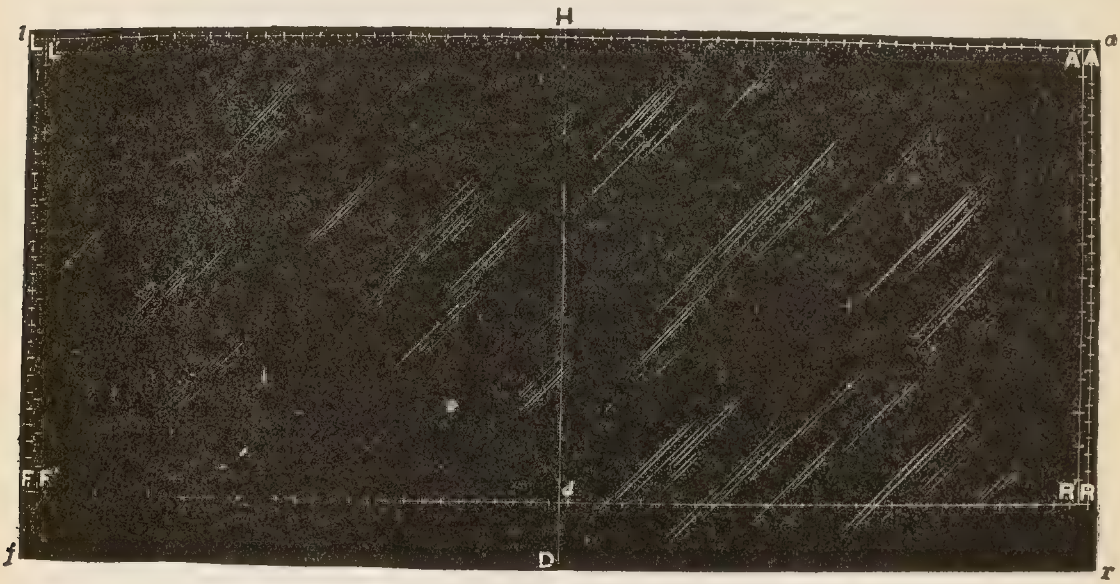


FIG. 9,727.—Complete layout for rivet lines and spacing of rivets for shell.

sheet hand holes are specified. These are elliptical in shape and are located with their major axes parallel with the upper and lower edges of the plate.

The size of these holes is not given but may be taken as $3\frac{1}{2} \times 5\frac{1}{2}$. First find height of major axes from lower edge of plate. This height is equal to height grate + height furnace + thickness tube sheet + $\frac{1}{2}$ minor axis.

Substituting values from drawings of boiler,

height hand hole centers $= 13 + 18 + \frac{3}{8} + 1\frac{3}{4} = 33\frac{1}{8}$ ins.

Now in fig. 9,728, locate on the shell *larf*, points M and S, each $33\frac{1}{8}$

ins. above the lower edge *fr*, and draw line MS. This is the center line for the hand holes. For 6 hand holes on MS, whose length is 127.5 ins.

$$\text{distance between centers} = 127.5 \div 6 = 21\tfrac{1}{4} \text{ ins.,}$$

Locate the centers so that the longitudinal seam will come midway between two adjacent hand holes. Hence the first and last centers will be $21\frac{1}{4} \div 2 = 10\frac{5}{8}$ ins. for the edges of the plate and the complete spacing as shown in fig. 9,728. Through these centers erect perpendiculars for the vertical axes and describe the ellipses 1,2,3, etc., with the dimensions given.

Opening for Furnace Door.—For accuracy in working to

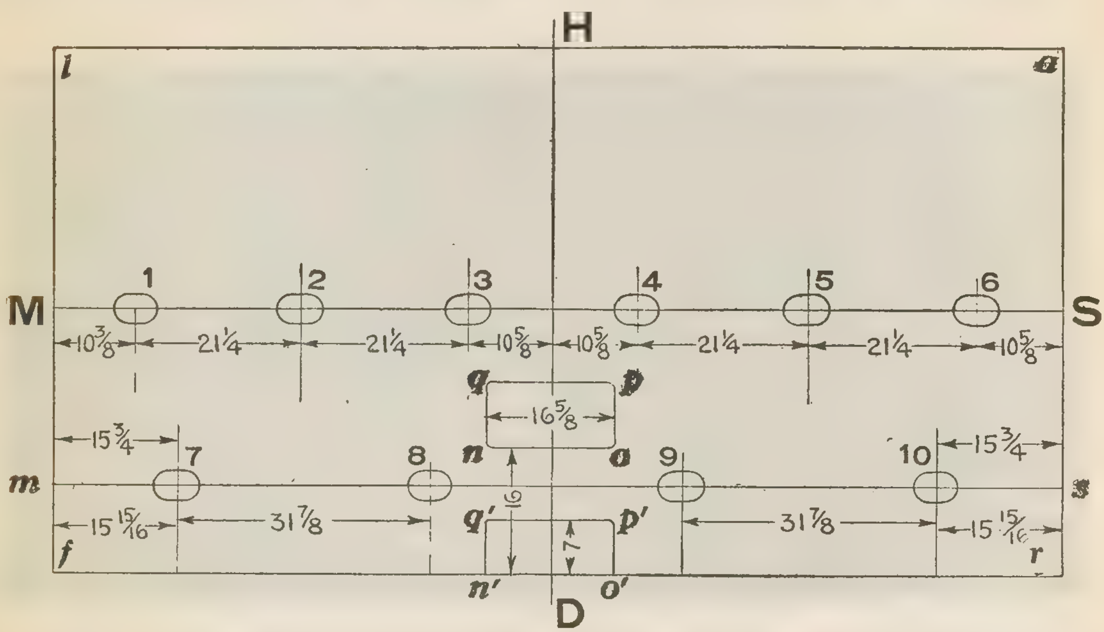


Fig. 9,728.—Layout for hand holes and opening for door.

dimension, allowance should be made for the curvature of the shell in fixing the length of the opening in the flat plate, which becomes an arc when the shell is rolled to shape of which the length of opening is its chord.

This may be obtained by calculation, or graphically as in fig. 9,729. The length as found will be the proper length to lay off on the flat plate.

In fig. 9,728, draw the lower edge of the door opening *no*, 16 ins. above *fr*, and complete the rectangle *nopq*, making *op* = 8 ins. As here located the door opening is midway between the ends of the sheet as indicated by the mid axis HD.

Water Leg Hand Holes.—The design fig. 9,705 specifies three hand holes, but since the door opening is located midway between the ends of the plate, this number, assuming equal spacing, will bring one hole under the door, or too near the seam.

Modifying the design for four holes,

distance between centers = 127.5 ÷ 4 = 31⅞ ins.

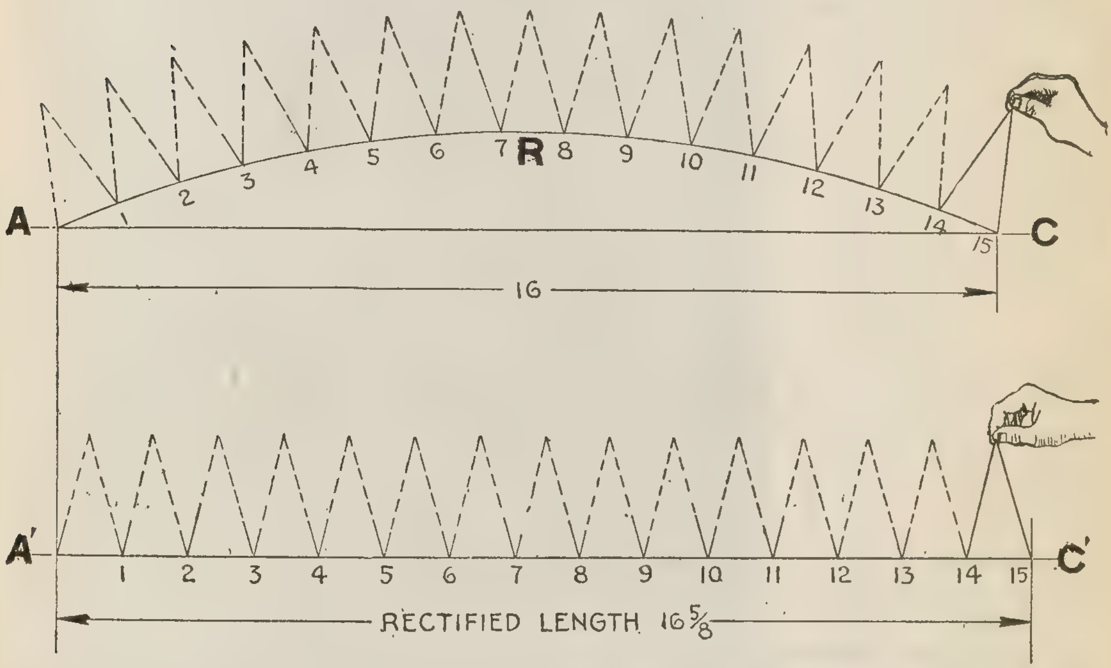


FIG. 9,729.—Method of rectifying arc with dividers. ***Set dividers*** so as to step off any number of divisions on the arc ARC. Draw another line A′C′, longer than AC, and step off with dividers the same number of divisions giving the length A′15, of the arc ARC.

In fig. 9,728, take height of centers 12 ins. above lower edge of plate, lay off $fm = rs = 12$ ins. and draw *ms*, center line of hand holes.

Locating the holes so seam comes midway between two adjacent holes, lay off *m*7 and S10 = 31⅞ ÷ 2 = $15^{15}/_{16}$ ins.

Describe ellipses with centers 7,8,9,10 thus found.

Ash Door Opening.—This opening *n′o′p′q′*, fig. 9,728 is

located directly below the furnace opening. Make $q'p'=n'o'$, and the height $o'p'$, equal distance to lower edge of furnace plate or $7\frac{1}{8}$ ins.

Tappings for Outlets.—For the proper operation of the boiler the following outlets are necessary:

2—¾ in. auxiliary outlets.
3—½ in. for gauge cock.

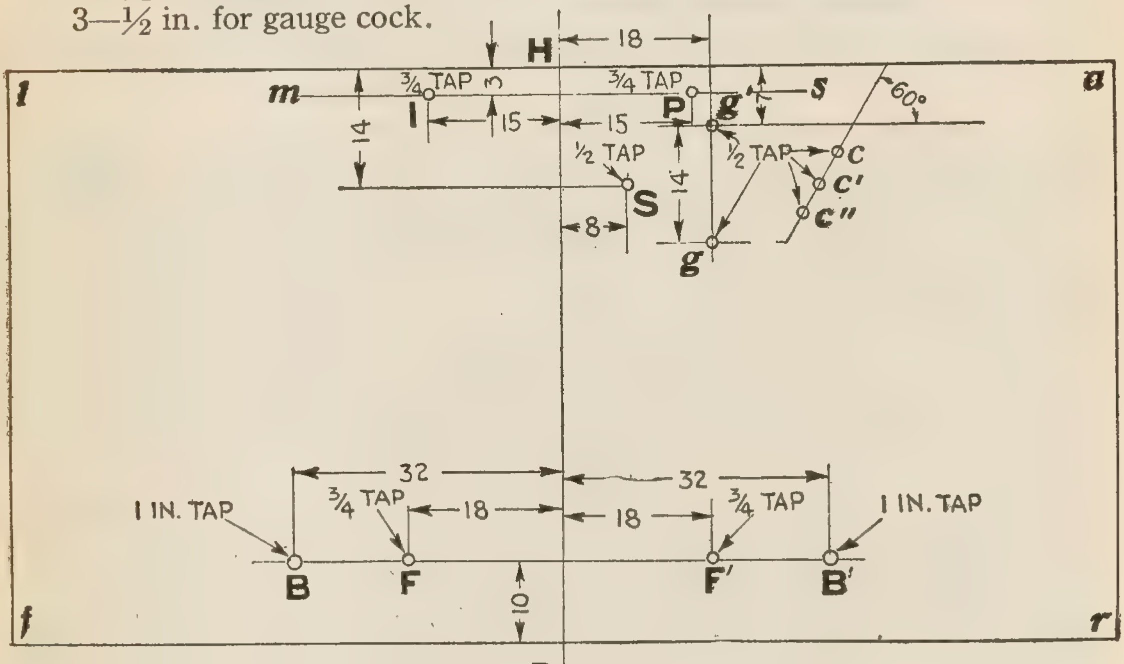


FIG. 9,730.—Layout for shell tappings.

2—½ in. for water gauge.
2—¾ in. for feed.
2—1 in. for blow off.

In fig. 9,730, draw line *ms*, 3 ins. below top edge *la*, of plate; this is the axis for the auxiliary outlets. These outlets are for steam supply to injector, pump, syphon, etc., and for convenience in operation should be located, say 45° on each side of the mid axis HD.

The corresponding spacing on plate in inches is:

$$\frac{45}{360} \text{ of } 127.5 = 14.17, \text{ say } 15 \text{ ins.}$$

Lay off this distance on *ms*, each side of its intersection with the mid arcs HD, giving centers I and P, for tapping.

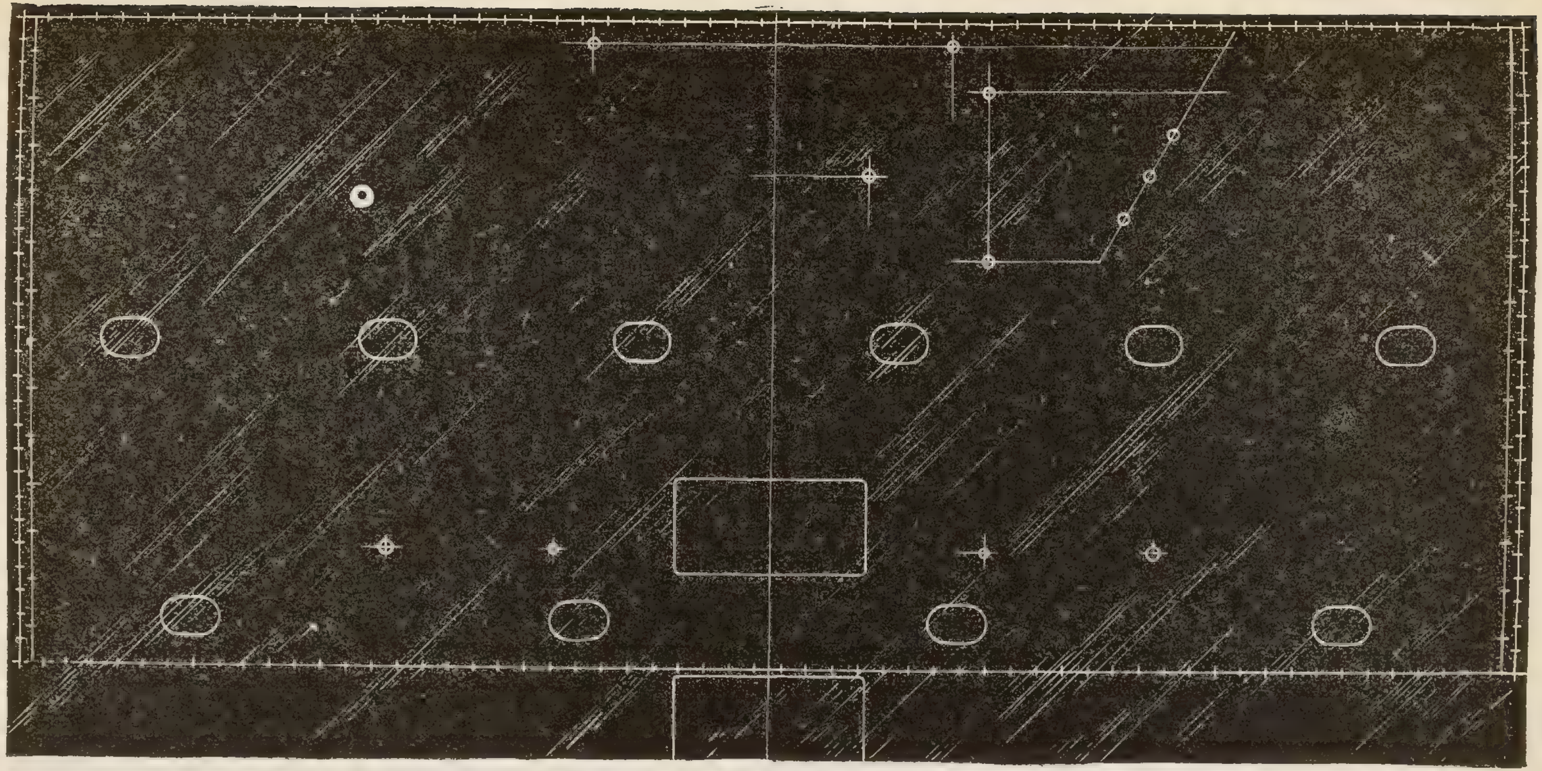


FIG. 9,731.—Complete layout for shell.

The layout for the other tappings somewhat modified for the original design are: B,B′, blow off outlets; F,F′, feed inlets; S, steam gauge; c,c',c'', water cocks; g,g', water gauge. Fig. 9,731 shows the complete layout for shell.

Tube Sheets.—For the high concentration of power required of this boiler, a large number of small tubes are required and in design, several trial layouts were made before the proper proportion was obtained.

Fig. 9,732 shows the layout selected. Since the same layout is required for both tube sheets it will perhaps for precision, be best to make a pattern and transfer the centers from pattern to sheets; this would moreover, save the trouble of making the same layout twice.

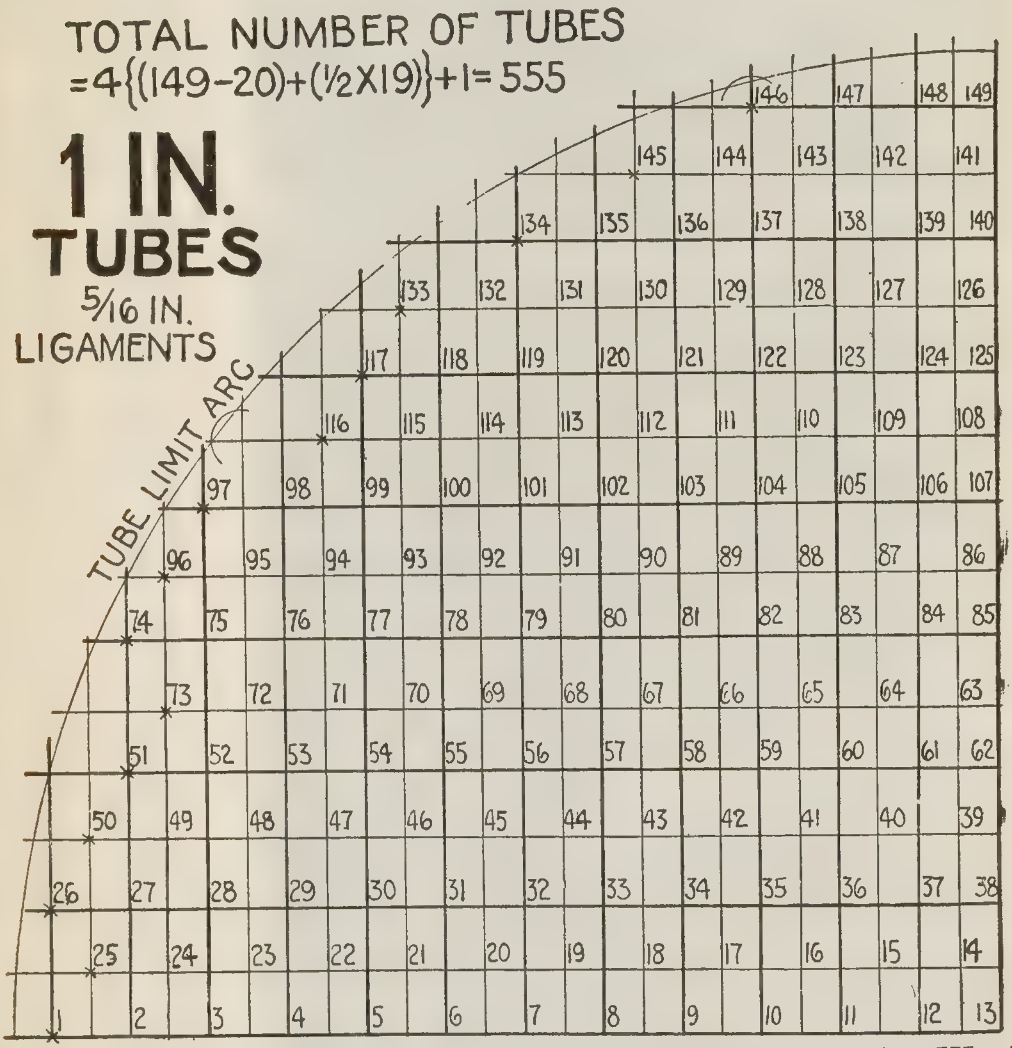
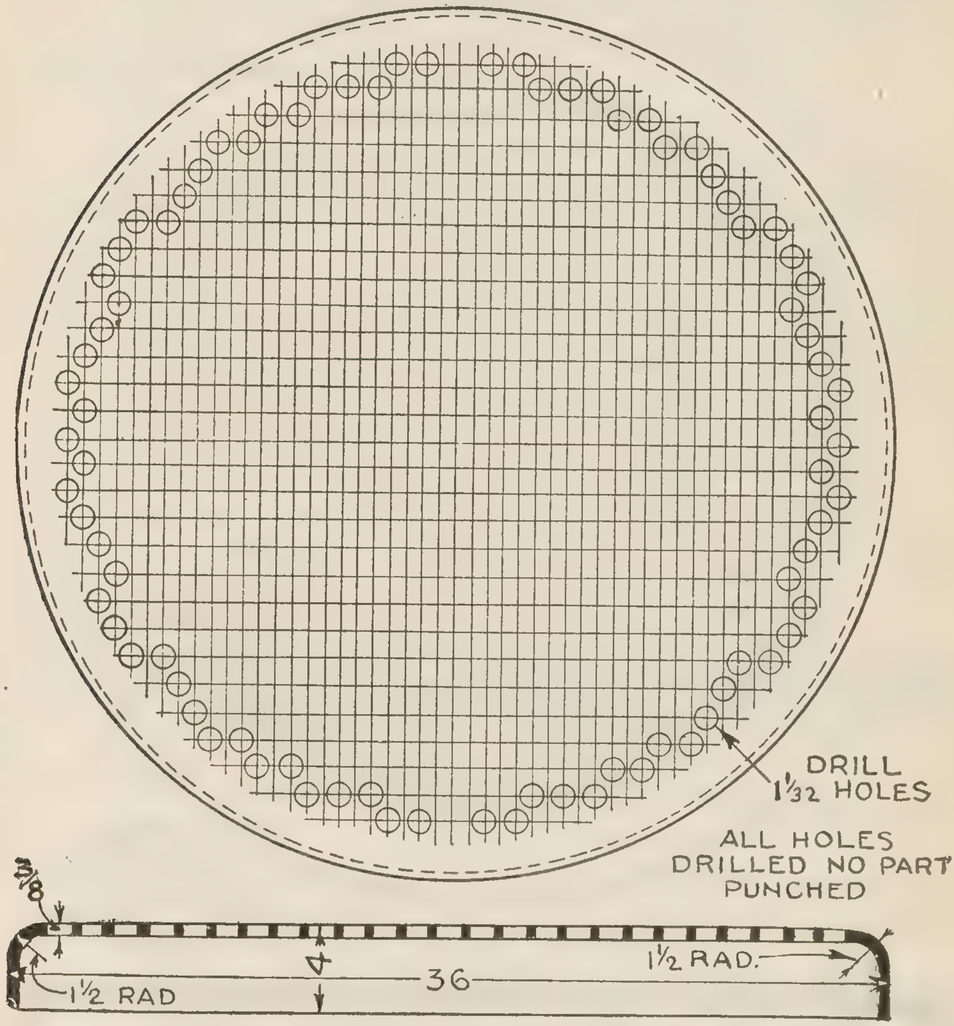


FIG. 9,732.—Trial tube sheet layout for *1 inch tubes* ⁵⁄₁₆ *inch ligaments*. This gives 555 tubes, each 2.9 ft. long or approximately 2 ft. 11 in. which is practically the 3 foot limit imposed in the design. The actual length of the tubes as cut from tubes of 12 foot length will be 3 feet less the thickness of the metal removed by cutting as shown in fig. 9,741.

If made directly on the sheets the layouts will appear as in figs. 9,733 and 9,735. The design of the sheets is shown in the sectional views, figs. 9,734 and 9,736.

Furnace.—This consists of a circular shell, riveted to the boiler shell at its lower end, and to the lower tube sheet at the upper end, being reinforced by stay bolts tapped radially



FIGS. 9,733 and 9,734.—Lower tube sheet. The holes are drilled 1/32 inch larger than the tubes, or 1 1/32 to allow easy insertion and removal.

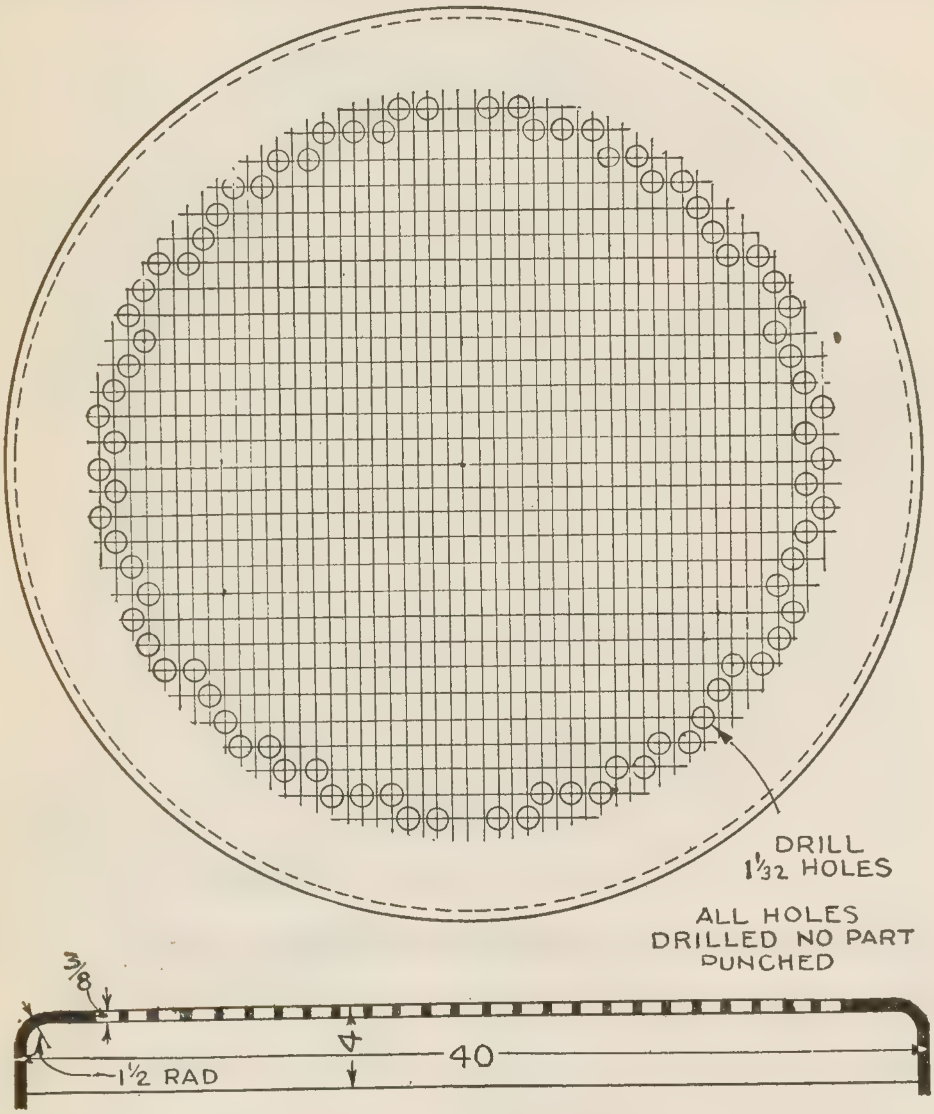
to furnace and boiler shell. Details of the furnace design are shown in the accompanying illustrations.

The furnace which is $^5/_{16}$ in. thick has a lap joint and a compound curve section at the bottom which is riveted to the shell instead of to a mud ring.

The compound curve is known as an *ogee* curve (hence the name ***ogee***

fire box). The layout of the plate for the fire box is similar to the layout for the shell and differs in that the lap joint must be considered and the flare for the *ogee* curve.

First find the net length of plate, making allowance for lap afterwards.



FIGS. 9,735 and 9,736.—Upper tube sheet, showing tube layout. The ligaments are 5/16 in. The centers are located by the method shown in fig. 9,732. The drawing does not show tappings for dryer connection or for smoke ring bolts. To correspond with the modified shell length, the diameter of tube sheet should be increased to 40.58 ins.

$$\text{net length plate} = \text{neutral diameter} \times 3.1416$$
$$= (36 + {}^5/_{16}) \times 3.1416 = 114 \text{ ins.}$$

In fig. 9,745, on line through H, measure off ½ of 114 or 57 ins. each

side of H, giving line *la*, or top edge of plate. Erect perpendiculars at *l* and *a*.

Set trammels to $15\frac{3}{4}$ ins. (obtained from fig. 9,737) and with *l* and *a*, as centers describe arcs cutting the perpendiculars at *m* and *s*. Draw line *ms*. The rectangle *lasm*, then, represents the portion of the fire box above the *ogee* curve. With a measuring wheel find lengths of arcs *mn* and *no'* of the *ogee* curve fig. 9,739.

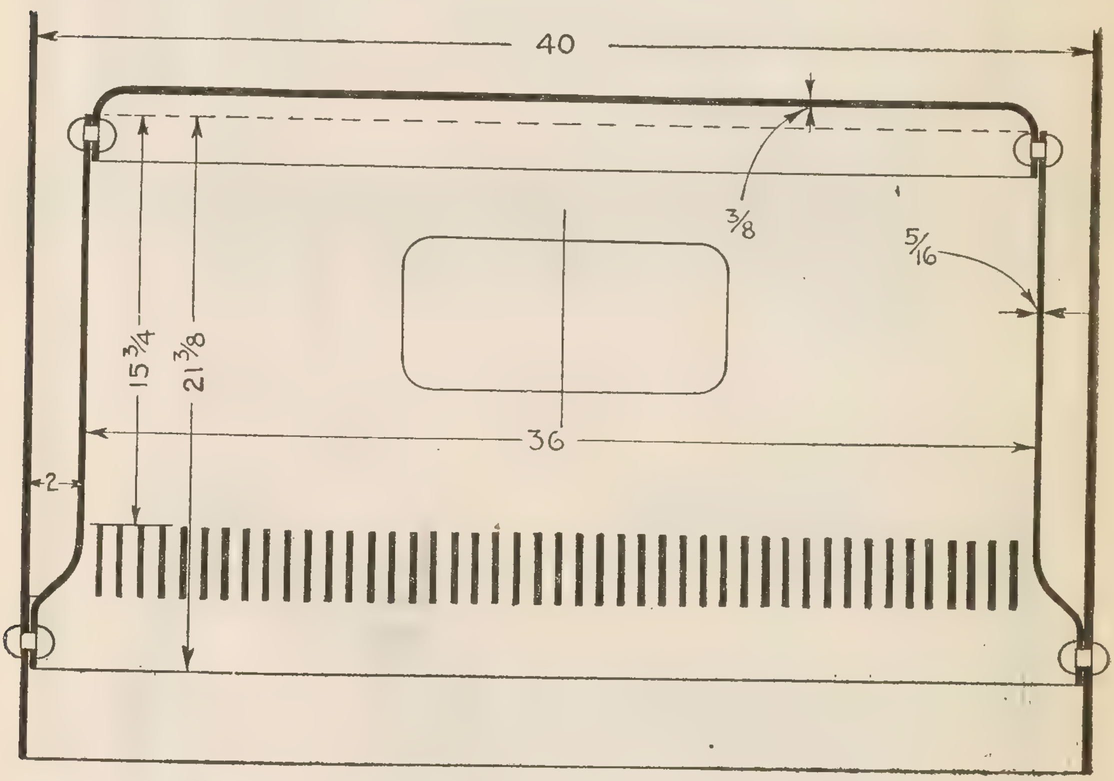


FIG. 9,737.—Detail of furnace with dimensions for layout.

If a measuring wheel be not available, these arcs may be calculated thus:

$$\text{radius of arcs} = 2 - \tfrac{5}{32} = 1\tfrac{27}{32}.$$

$$\tan\theta = 3\tfrac{1}{8} \div 1\tfrac{27}{32} = 1.694. \quad \text{(see fig. 9,743)}.$$

θ from table of natural trigonometrical functions * = 59° 30′.

Now,

$$\text{circumference of } 3\tfrac{11}{16} \text{ circle} = 3\tfrac{11}{16} \times 3.1416 = 11.58 \text{ ins.}$$

*NOTE.—For table reading to degrees see the Author's Plumbers and Steam Fitters Guide No. 1, page 1,129.

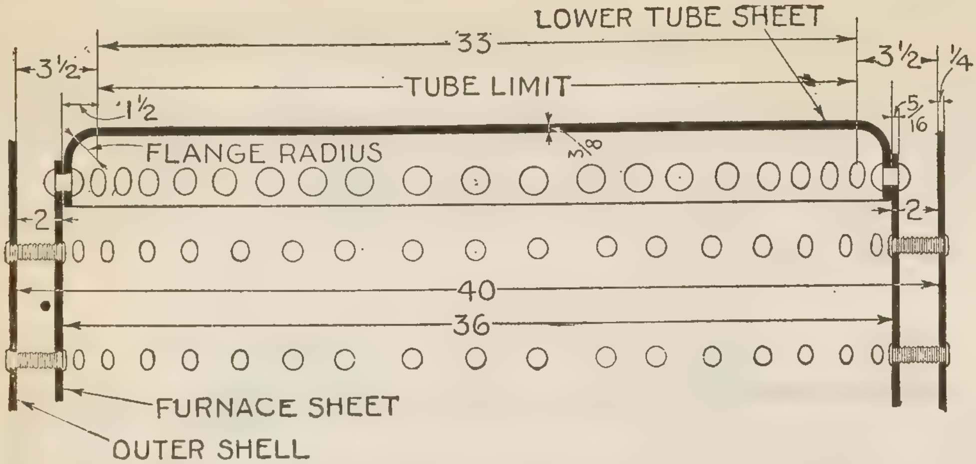
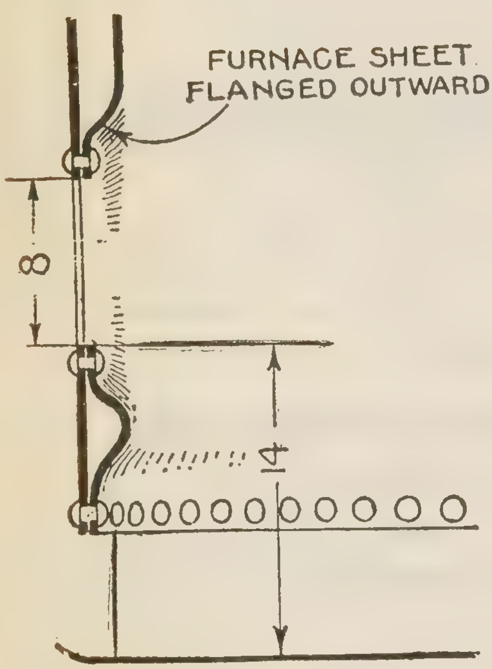
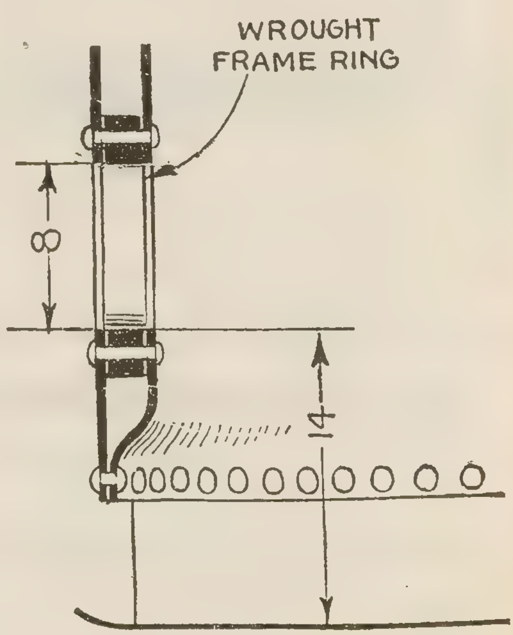


FIG. 9,738.—Detail of lower tube sheet showing diameter of surface available for tube layout. ***As shown,*** the shell diameter of 40 inches is reduced 2 inches each side by water leg and furnace sheet and an additional 1½ in. must be allowed on each side for flanging leaving 40 – (2×2 +2×1½) =33 ins. available in tube sheet section for tubes.





FIGS. 9,739 and 9,740.—Fire door opening constructed between shell and furnace sheet. Fig. 9,739, outwardly flanged furnace sheet riveted to shell; fig. 9,740, wrought frame ring construction.

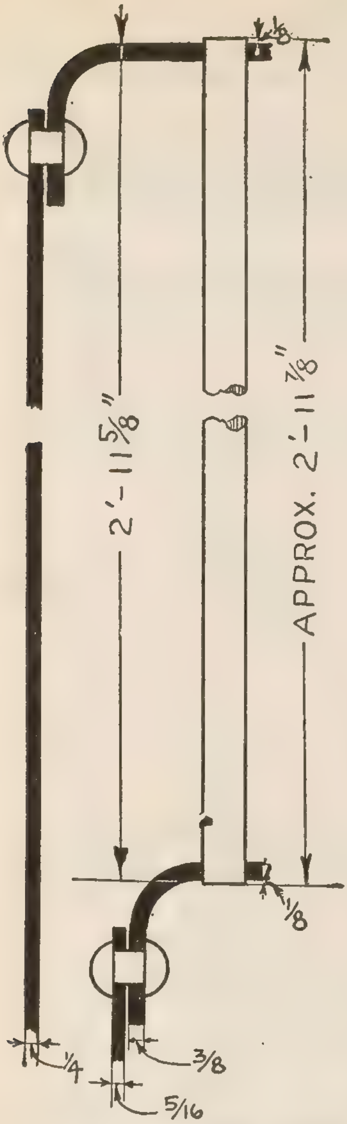
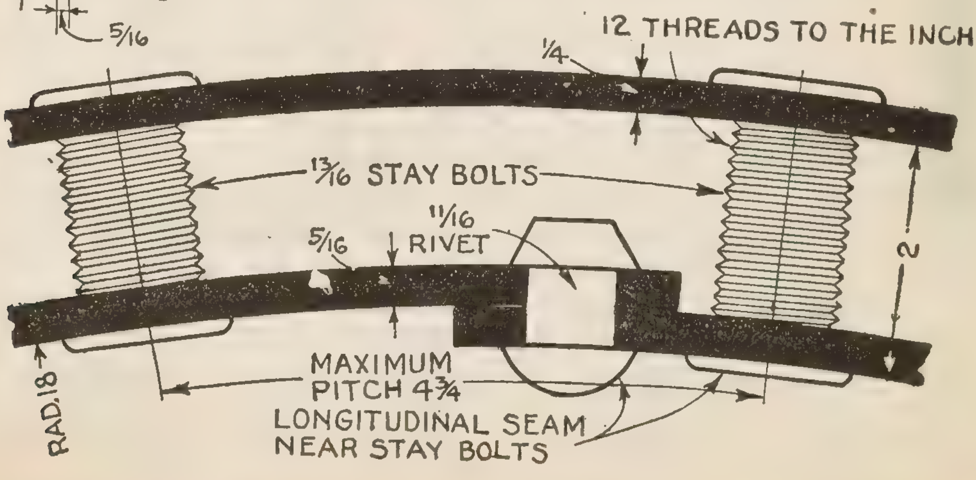


Fig. 9,741.—Detail of tube and sheets showing allowance for cutting and tube margin outside of sheets for beading.

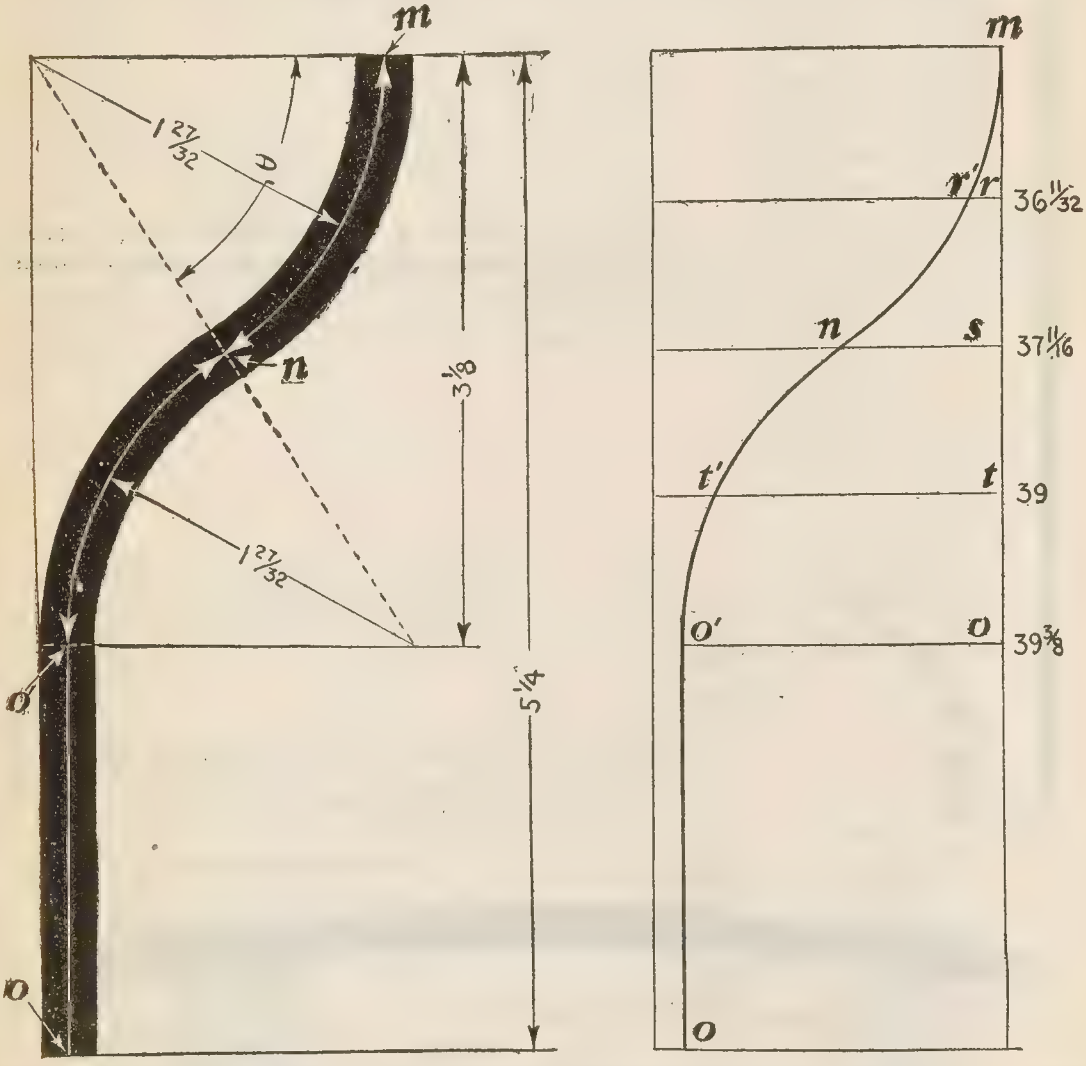
Fig. 9,742.—Section of shell and internal cylindrical furnace showing proper location of stay bolts adjacent to longitudinal joint in furnace sheet.



$$\text{length of each arc} = 11.58 \times \frac{59.5}{360} = 1.91 \text{ in.}$$

Now in fig. 9,745 lay off *ms'*, and *s' o*, each = 1.91 ins. and through *s* and *o*, draw lines parallel to *ms*.

Enlarge the *ogee* curve as in fig. 9,743 and reproduce the parallels to scale. At the points of intersection of the parallels with the *ogee* curve, the diameters and circumferences, and half circumferences are



FIGS. 9,743 and 9,744.—Detail of ogee section of fire box and skeleton diagram for obtaining measurements for layout of the ogee curve.

Point	Diameter	Circumference	Half Circumference
r'	36 11/32	114.19	57.1
n	37 11/16	118.42	59.21
t'	39	122.54	61.27
o'	39 3/8	123.73	61.87

Lay off in fig. 9,745 the half circumferences from the mid axis to the left giving the points r',n,t',o', through which the *ogee* developed curve passes. Lay out the similar curve $sr''n't''o''$ on the other side of the mid axis.

Allowing 2¼ ins. for the lap joint, lay off aa' = 2¼ ins. and draw edge $a's''n''o'''$, parallel to $asn'o''$. The shaded area between the two parallels indicates the amount the edge $a's''n''o'''$ laps over edge $mr'nt'o'$, when the plate is rolled.

Now in fig. 9,737, there is below the *ogee* portion, a cylindrical portion of the plate for the lower circumferential joint, which as shown extends

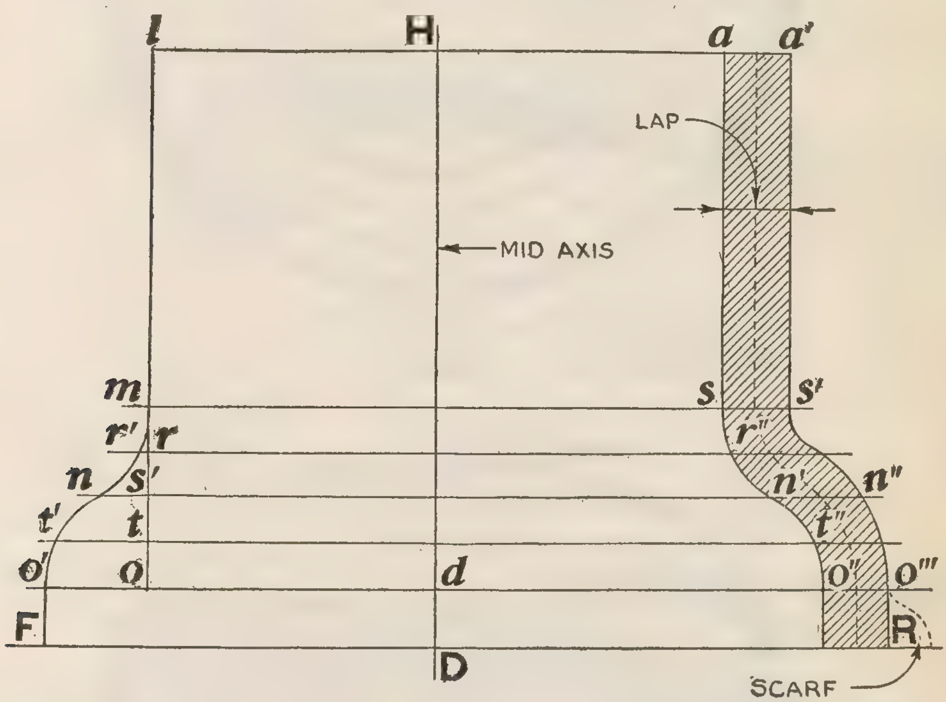
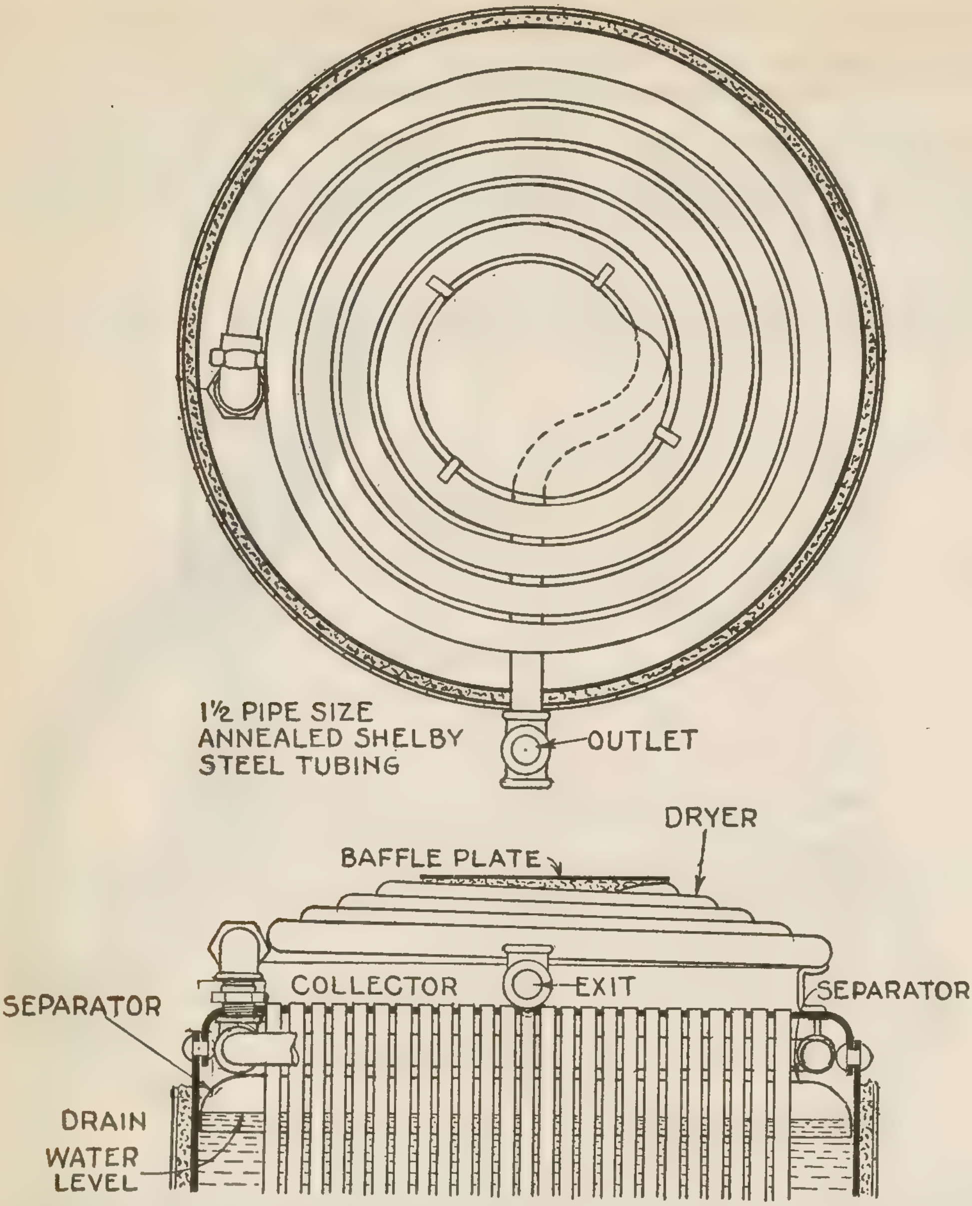


Fig. 9,745.—Layout for furnace plate.

downward 2⅛ ins. Hence in fig. 9,745, lay off dD = 2⅛ ins., and draw a line parallel to $o'o'''$, and through o' and o''', draw lines parallel to the mid axis cutting the parallel just drawn in points RF. The outline of the plate as thus laid out in laRF.

With a lap joint some provision must be made to close up the opening that occurs where the lap joint connects with the circumferential joints.



FIGS. 9,746 and 9,747.—Detail showing upper tube sheet, separator, collector and dryer. The ***separator*** is made of thin sheet metal about No. 12 gauge and is shaped as shown, extending over to the tubes. This forces the steam arising from the liberating surface near the shell to pass over some of the tubes, and suddenly change its direction throwing it against the hot tubes before entering collector. The holes in the collector being on the upper side near the top, the steam makes a second change of direction before entering the collector, thus giving two fold separation. The ***collector*** is made of light tubing and encircles the boiler tubes, the ends being tightly joined to a special T. 3/16 holes spaced about 1 inch apart should be drilled all around the outer side of the collector at 45° to the vertical. The ***dryer*** is connected with the collector by a short nipple elbow and union. It consists of a spiral coil as shown. This coil should have a liberal number of convolutions, the diameter of the innermost turn being as small as advisable for the size pipe used. The T near the outlet is for branch to safety valve. This T should be special so as to bring top of collector within ½ in. of tube sheet.

Thus in fig. 9,748, this opening is shown in solid black of curved triangular cross section *laf*, and is due to the inner end of the plate terminating at *lf*. To close up this opening a projection is added to the plate and scarped to conform to the shape of the opening as in fig. 9,749. The shape of the projection is perhaps better seen in fig. 9,750 and is shown in the layout fig. 9,745 in dotted line.

The method of laying out the rivet lines and spacing of the rivets is similar to that for the shell. Here single riveting is employed for all seams and there are no straps.

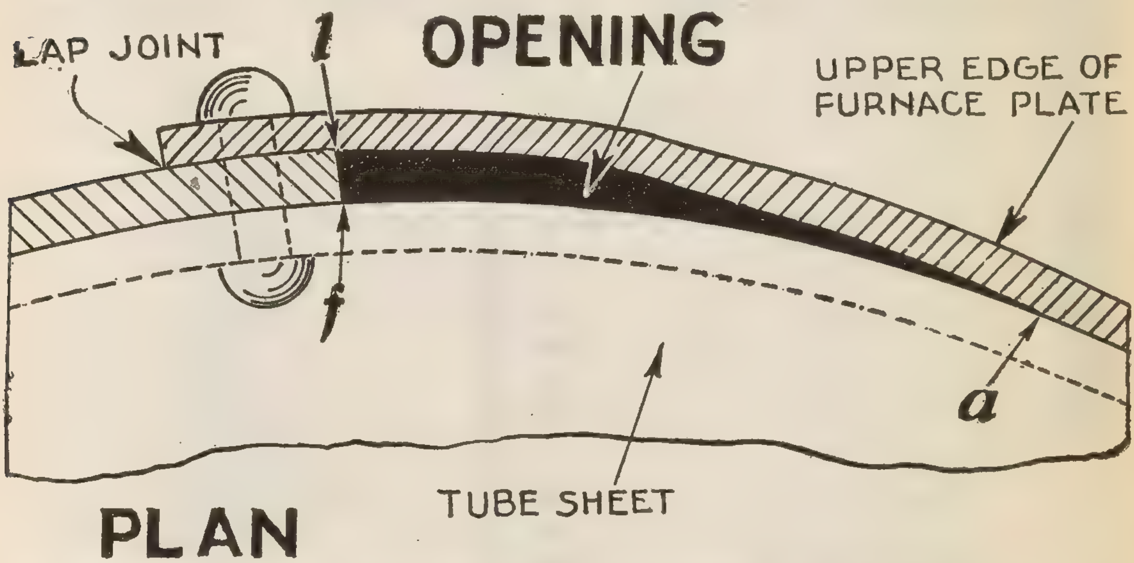


FIG. 9,748.—Detail of lap joint showing shape of the opening due to the lap.

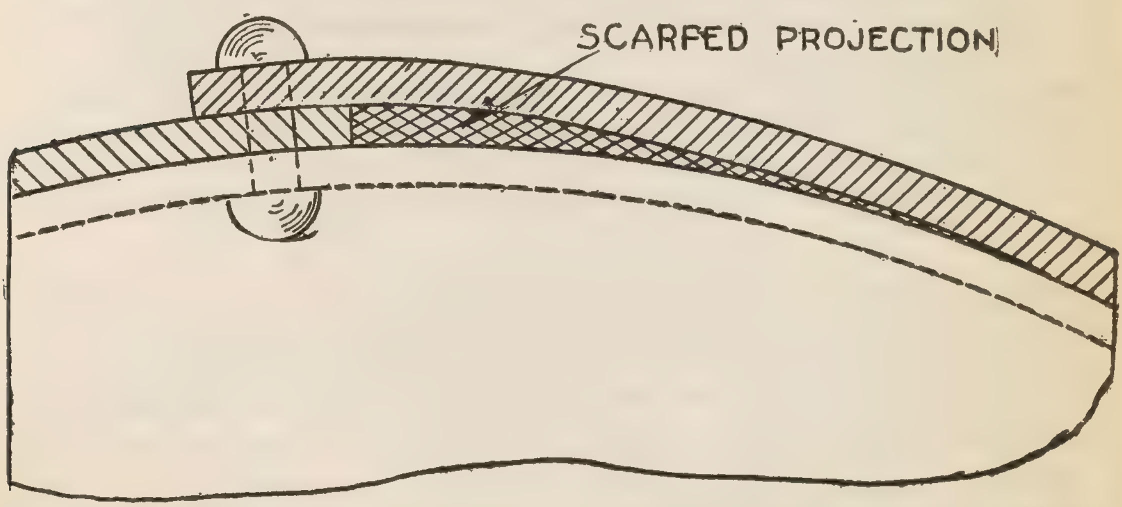


FIG. 9,749.—Detail of lap joint showing scarped projection to close the opening *laf* shown in solid black section in fig. 9,748.

It remains to lay out the opening for door, and as the metal has to be dished outward so it will rivet to the shell, a margin of metal determined by experience must be allowed to provide for this. Fig. 9,739 shows the dishing or outward flanging around the furnace door opening.

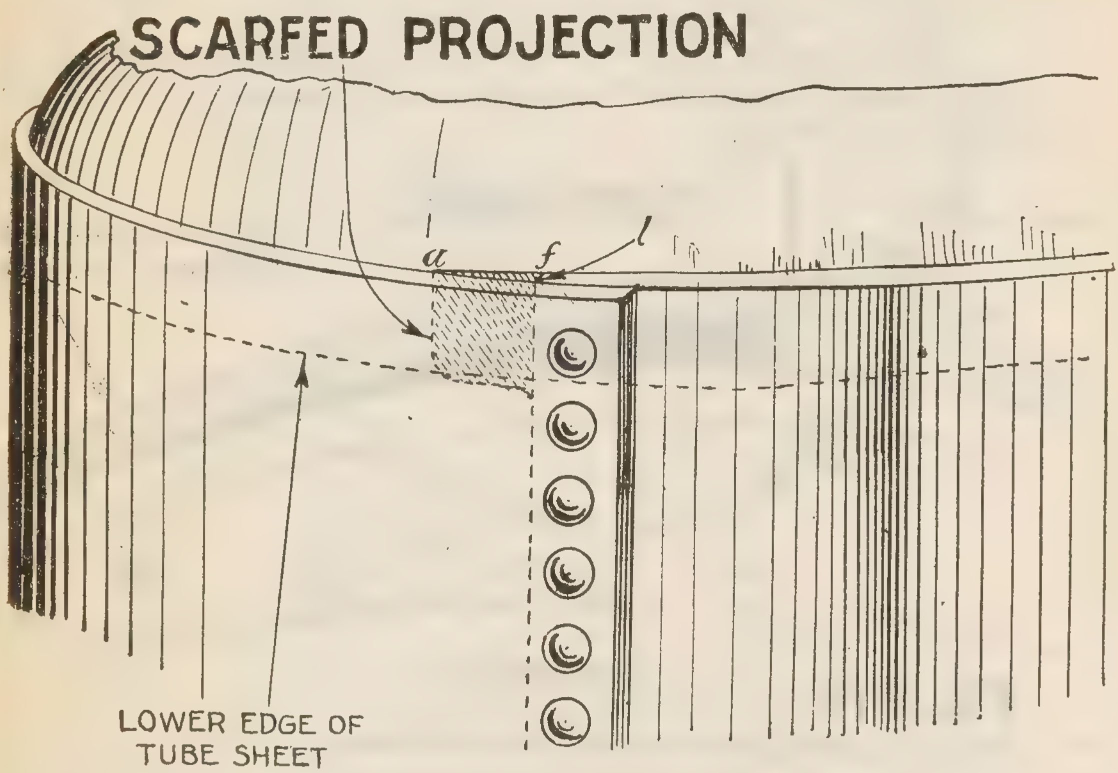


FIG. 9,750.—View of scarfed projection to close up the opening *laf*.

CHAPTER 150

Sheet Metal Machines

Sheet metal work is a large and growing industry. It is closely connected with the building trades in turning out such work as cornices, roofing, skylights, ornamental ceilings, ventilating and heating pipes, etc. The various machines and tools forming the equipment of a sheet metal working shop may be classified as

1. Floor machines
2. Bench machines
3. Stakes
4. Hand tools
5. Soldering equipment.

There is a great multiplicity of machines of each class available and the proper selection of these tools for any particular shop will depend upon the kind of work to be done and special care should be taken to choose such machines and tools to properly turn out the work required of the shop.

The layout of a small sheet metal shop is shown in fig. 9,751. This plan is for a general shop in which sheet metal work is combined with some occupation, as for instance, the sheet metal department of a plumber's shop. The layout is based on the idea of using one corner of a room approximately 25×30. The following equipment will be sufficient for 4 to 6 workmen.

Bench Machines

1 30 in. Improved sheet iron folder;

1 Bench machine with stand, with one pair each 3/16 turning rolls, burring rolls, wiring rolls, crimping rolls, 3/16 in. single beading rolls and 3/4 in. O. G. beading rolls.

1 2×30 in. Niagara slip roll former.

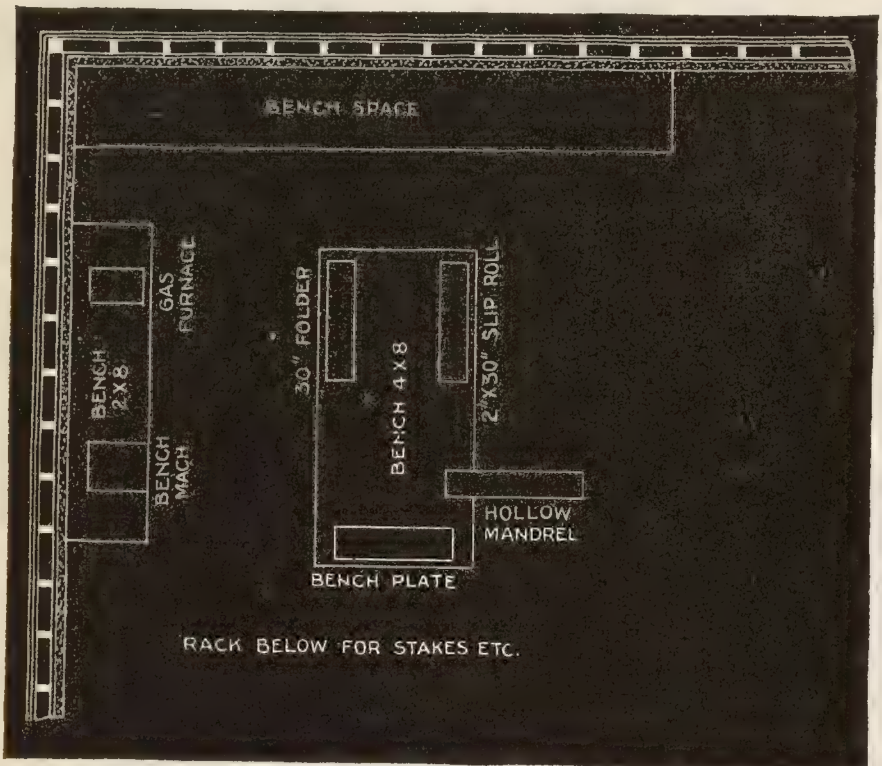


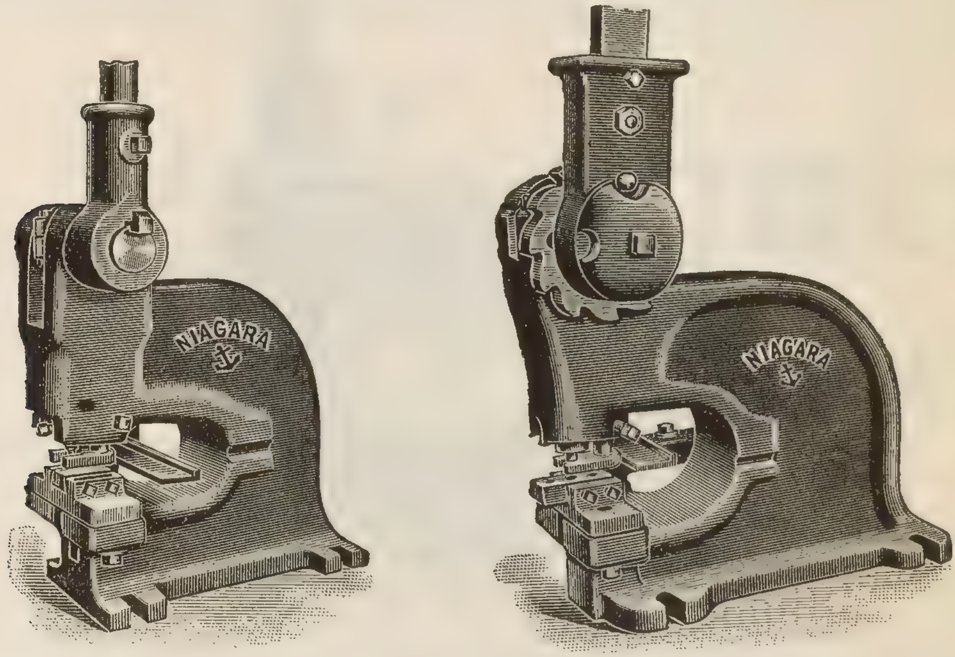
Fig. 9,751.—Layout for small sheet metal shop.

Stakes

1 Beakhorn stake, No. 2
1 Blowhorn stake
1 Needle case stake
1 Common square stake
1 Hatchet stake, No. 5
1 Hollow mandrel, No. 0
1 Bench plates—8×37 in. No. 1.

Hand Tools

4 Straight snips
1 Circle snips
1 Bench shear
1 Set of 3 rivet sets: Nos. 0, 2 and 5
1 Set of 2 grooving tools: Nos. 3 and 5
1 Set of 2 hollow punches, $\frac{3}{8}$ and $\frac{1}{2}$ in.
1 Set of solid punches, $\frac{9}{32}$, $\frac{7}{32}$ and $\frac{9}{64}$



FIGS. 9,752 and 9,753.—Niagara lever punches, intended for punching small round holes. Adjustable back gauge regulates the distance from the holes to the edge of the sheet and a stripper removes the stock from the punch at the upstroke. Fig. 9,752 shows a small punch for $\frac{1}{4}$ in. hole through $\frac{1}{4}$ in. iron or equivalent. The lever works both ways, front and back. $\frac{7}{32}$ and $\frac{9}{32}$ in. holes can be punched in angle iron with flange downward, if the center of the hole be not less than $\frac{1}{2}$ in. from the inner corner. Fig. 9,753 shows a ratchet lever punch. It can be operated with or without ratchet, according to the work. If used direct, the lever works both ways, and with the ratchet toward the back of the machine. Without ratchet, $\frac{1}{2}$ in. hole through $\frac{1}{4}$ in. iron. With ratchet, $\frac{1}{2}$ in. hole through $\frac{3}{8}$ in. iron or equivalent. $\frac{9}{32}$ and $\frac{13}{32}$ in. holes can be punched in angle iron with flange downward, if the center of the hole be not less than $\frac{1}{2}$ in. from the inner corner.

1 Prick punch
4 Scratch awls
4 Riveting hammers, No. 3

1 36 in. plain circumference rule
4 2½ in. hickory mallets
1 Cutting nipper
1 10 in. wing dividers
1 2 ft. steel squares
1 6 in. flat nose pliers
1 ⅝ in. cold chisels.

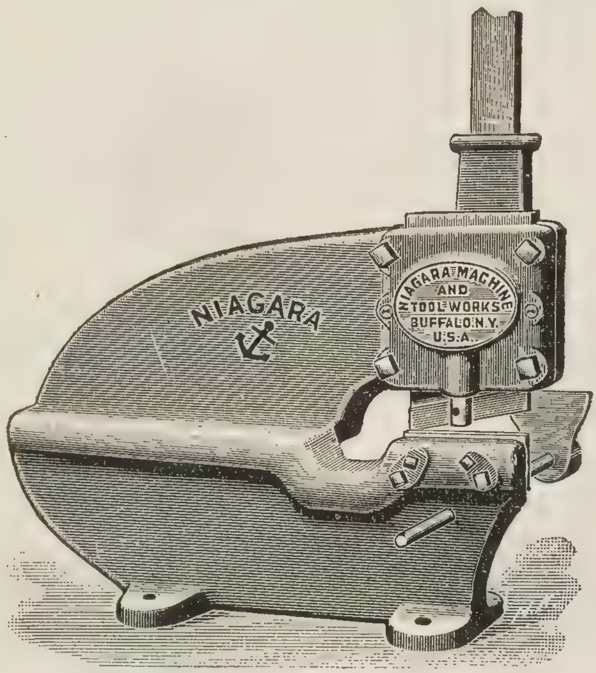


Fig. 9,754.—Niagara lever shears, suitable for cutting apart sheets of any length and width. The extreme capacity can be obtained only in cutting off strips, not in splitting sheet on account of the force used in bending the stock. ***In operation,*** the lever works toward the front and one man can operate the machine. The knives are adjustable for wear. The hold down attachment prevents the material rising while being cut and an adjustable gauge is provided.

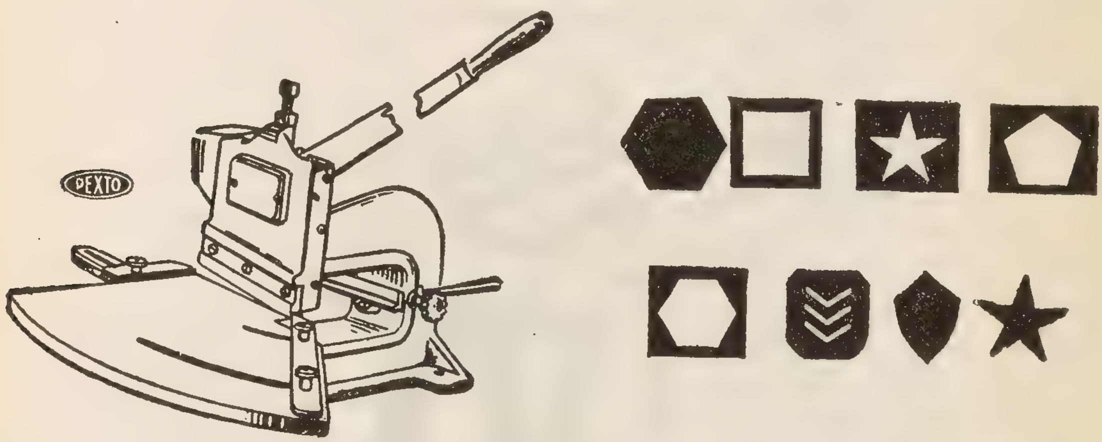
Soldering Equipment

1 Double burner gas furnace
1 Pair soldering coppers, 3 lb. per pair
2 Soldering copper handles.

The machines ordinarily used are described in the following paragraphs:

Squaring Shears.—All stock for articles made of sheet metal must first be cut from the original sheets. The machine used for this work is the squaring shear. It may also be used for much straight cutting in trimming stock to exact sizes. The cut is made in straight lines only and the machine has guides and gauges to be used in squaring and cutting to the required widths and lengths.

Usually the work is inserted from the front of the machine, but long sheets may be worked from either front or back. The side guides should



Figs. 9,755 to 9,763.—Pexto "Utility" slitting shears and samples of work cut from blanks to line. These shears will do the work of ord nary bench shears, over which they have the following advantages: The length of cut is longer to the same movement of the hand; the same pressure of the hand will cut thicker stock; they cut with the same ease at all points of the cut, while ordinary bench shears cut harder near the point than near the bolt. The lower blades of these shears are stationary, so that when cutting to line, the mark may easily be followed with accuracy. The blades are so constructed that the line drawn is always exposed to the view of the operator.

always be used in squaring work. Care must always be taken to keep fingers from under the blade. The work should be held down firmly on the bed of the machine while cutting. It will be advisable not to depend on the scale marked on the bed for accurate work. A steel rule should be used to check the setting. Keep the blades well oiled.

The method of operating a foot power squaring shears is shown in fig. 9,764 and the combination of a power squaring shears in fig. 9,765 and the combination of a power squaring shears in fig. 9,765.

Circular Shears.—The ring and circular shears has inclinable

cutters for cutting circles for the bottoms of vessels, etc., as well as cutting a circle inside of a circle or cutting a circle from a square sheet. A perfect burring operation demands that the bottom to be burred should be cut with extreme accuracy. Circles can be cut with the hand circular snips, but not with the same accuracy as the circular shears will produce.

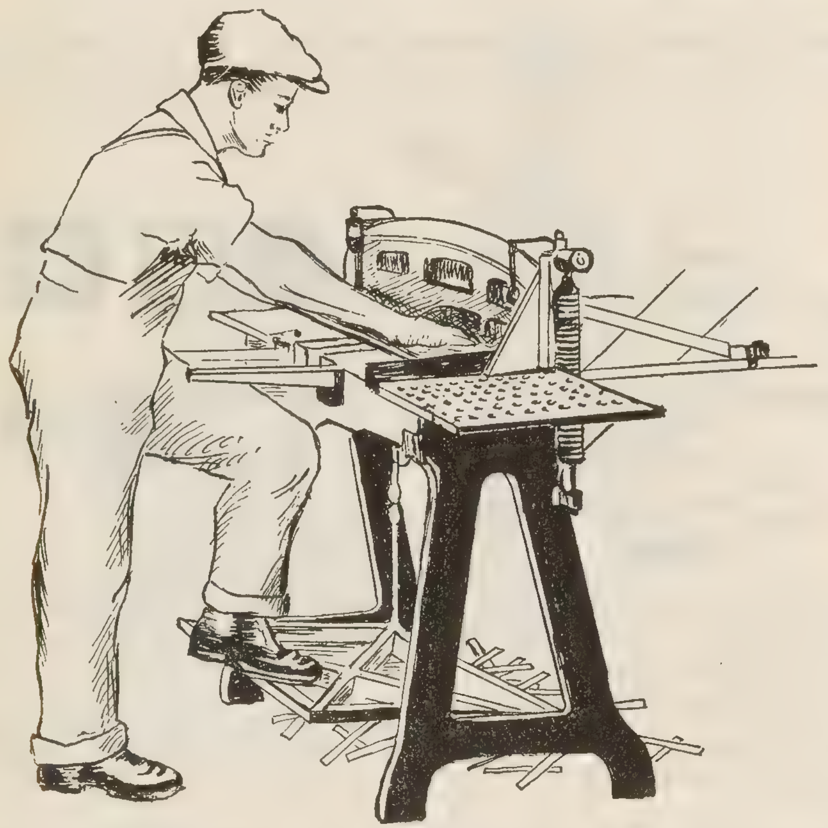


FIG. 9,764.—Squaring shears. They are used for trimming and squaring sheet iron. ***In selection,*** decide on the length of shears that will answer all requirements and the heaviest sheet metal that will be cut. Then select the type of shears best suited for the requirements.

The shears consist of a base and cutting head, with parallel cuttershafts driven with gears by means of a hand crank, or with a belt when the machine is arranged with pulleys for power drive. A sliding circle arm is fitted to the base and is adjustable for different diameter circles by sliding on the base to and from the cutters. The blank from which the circle is to be cut must be squared previous to cutting the circle. After being squared true and of a correct size nearest to the size circle to be cut, providing for as

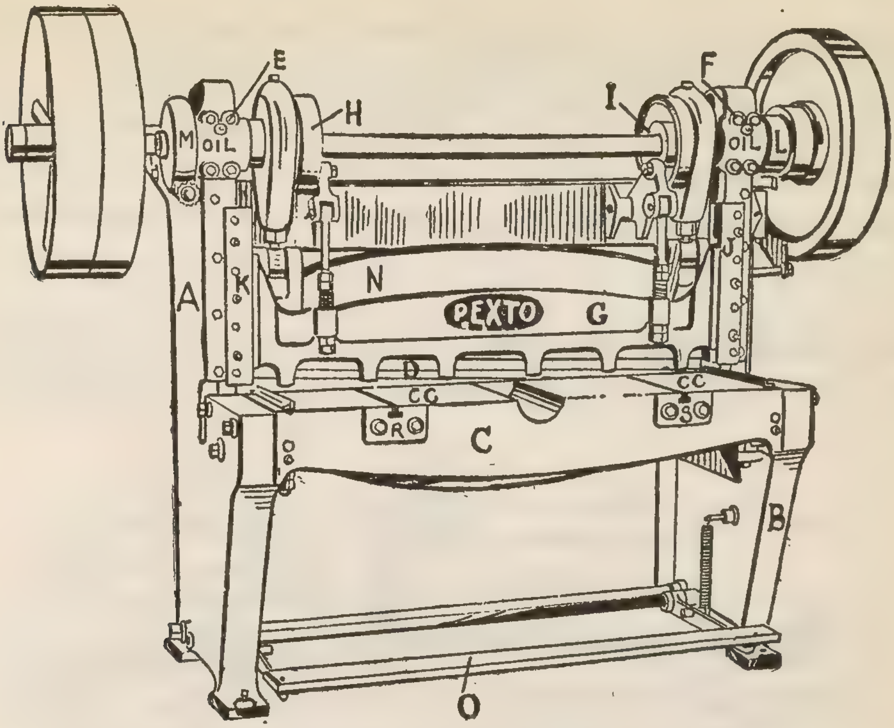


FIG. 9,765.—Pexto power squaring shears with overhead drive and gap in housing for permitting the trimming of sheets before squaring. ***In construction,*** the bed C, is accurately planed and bolted to the housings A and B, and it can be shifted towards or away from the upper cutting blade D. Graduations in fractions of an inch are cut in the bed along gauge slots CC. Gauge extension arms are fastened to the bed C, at R and S, and are held with two bolts for each arm.

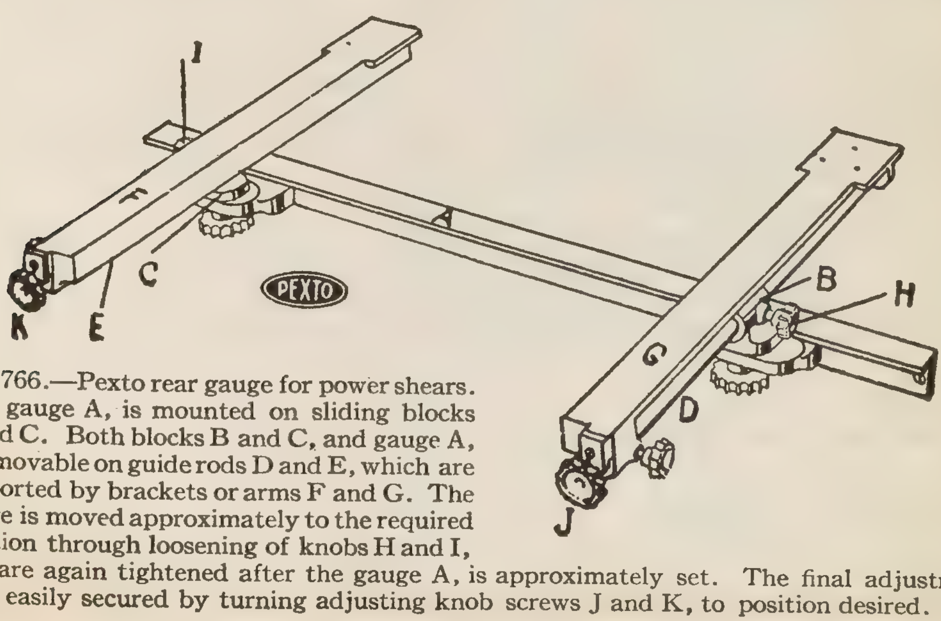
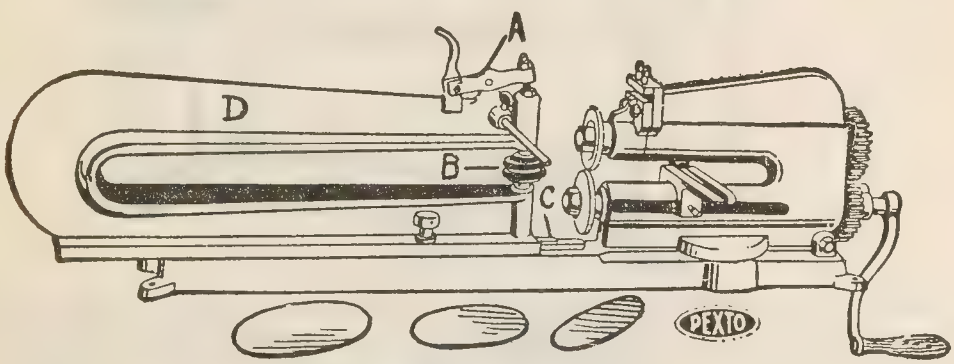


FIG. 9,766.—Pexto rear gauge for power shears. The gauge A, is mounted on sliding blocks B and C. Both blocks B and C, and gauge A, are movable on guide rods D and E, which are supported by brackets or arms F and G. The gauge is moved approximately to the required position through loosening of knobs H and I, and are again tightened after the gauge A, is approximately set. The final adjustment is then easily secured by turning adjusting knob screws J and K, to position desired.

little waste as possible, the square blank is inserted between two clamping discs in the circle arm. Through an eccentric clamping lever, or with a crank screw or a hand wheel, according to the design of the machine, the blank is securely clamped and the rotating of the cutters draws the material through the machine, cutting a true circle.

Figs. 9,767 to 9,770 shows a typical circular shears and work done by same.

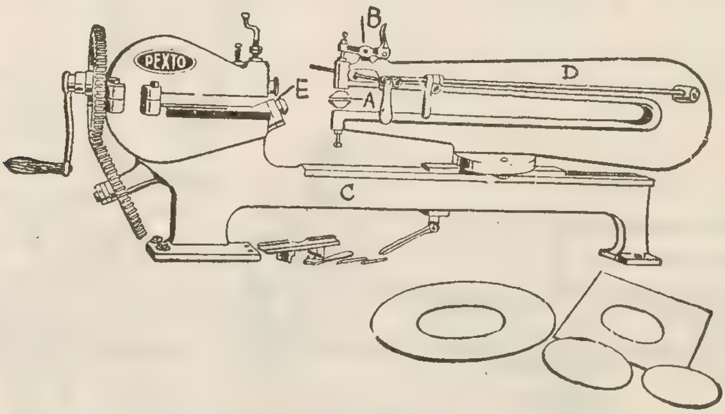
Ring and Circular Shears.—This type shears is intended for cutting both outside and inside circles and irregular curves.



FIGS. 9,767 to 9,770.—Waugh's circular shears and work done by same. A, eccentric lever to quickly clamp material between discs. A graduated scale is attached to the bed C, for the purpose of securing quick and accurate adjustment of the sliding arm D. The clamping discs B, are rubber covered which prevents slipping of the blanks. ***In operation,*** if for instance, a circle 5 ins. in diameter is to be cut, proceed to loosen the lock nut on the circle arm and set the sliding circle arm, drawing it to or from the cutters until the correct position of the cirlce arm is secured. With indicator on circle arm pointing to 5 ins. on the scale, lock the circle arm securely through the lock nut. Place the square blank between the clamping discs in a central position of equal distance on all sides of the blank from the outside diameter of the clamping discs. If many of the same size of circles are to be cut, after the correct first setting, adjust the swinging gauge so it will strike the edge of the square blank while remaining in the clamping discs. The machine properly set, any number of the same size circles can be cut accurately. Care should be exercised not to allow the cutters to have too much clearance or to rub against each other too hard; and when adjustment of the cutters for more or less cutter clearance is necessary, the lower shaft to which the lower rotary cutter is attached can be drawn away or to the upper cutter by means of the adjusting clasp nut on the lower shaft next to the gear. After the correct adjustment is secured, be sure to fasten the adjusting clasp nut securely. The upper cutter shaft bearing is adjustable and will raise or lower, allowing for the taking up of the wear of the cutters; and this adjustment should never be tampered with while the cutters are in good condition.

For ordinary outside circle cutting, the ring and circular shears does the same work as already described under circular shears and owing to the cutter raising feature in the ring and

circular shears, it is not so limited in the work performed. In addition to doing the work already described, the ring and circular shears offers a suitable means for cutting irregular curves when following a scribed line, and for such work the sliding circle arm is not used. The rotary cutters being of small diameter, measuring approximately $1\frac{5}{8}$ ins. in diameter, and set angular in position, they will cut as true and clean on the inside as on the outside of a sheet of metal.



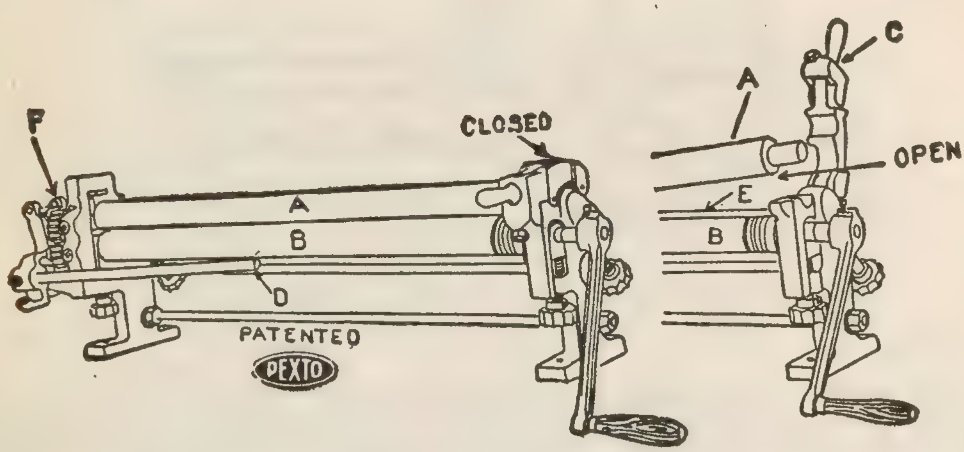
FIGS. 9,771 to 9,775.—Pexto ring and circular shears and work done by same. ***In construction,*** rubber covered clamps A, are provided for securing the material to the cut. Clamps operated by quick acting lever B. The bed C, on which the tail piece D, slides, is graduated in ins. and fractions of ins. for quick setting of the tail piece D, for the size circle to be cut. The angular position of cutters E, allows for as clean cutting on the inside as on the outside of circle. ***In operation,*** to cut an "internal" circle or circle out of a circle, for making a ring, or to cut a circle from the inside of a square sheet of metal, the prepared blank is clamped between the clamping discs in the usual way, and the sliding circle arm with the sheet metal blank inserted is brought toward the cutters, permitting as much of the edge of the sheet metal blank as necessary, according to the size of the inside circle that is to be cut, to slide between the cutters. With the proper alignment of the blank in the machine secured, bring the upper cutter down on the material by turning the crank screw hard enough, so that the cutters will cut the material without burring or buckling the edge. The ring and circular shears has in addition to the regular swinging gauge a ring gauge which slides on a rod along the circle arm for facilitating the cutting of rings, and through the proper setting of both gauges many quantities of the same kind and size of circles and rings can be cut alike with accuracy.

In using this machine never allow the cutters to have too much clearance or to rub against each other too hard; and when adjustment of the cutters for more or less cutter clearance is necessary, a satisfactory adjustment of the cutters is secured through the adjusting clamp nuts next to the gears on both the upper and lower shafts.

In cutting circles of a very small diameter, and sometimes when cutting

a small circle inside of a circle for making a ring, if on the edge of the material there should appear a burr or a buckle, this indicates that the circle arm is in too straight a line with the center of the cutters; and in such case the circle arm must be set a trifle out of line with the center of the cutter, just enough for cutting a true and clean edge. This adjustment is secured through loosening the bolts marked A, in the sliding circle arm plate and moving the circle arm as necessary until a proper adjustment is secured for assuring a clean cut.

Forming Machine.—This machine is used for bending sheet metal or wire to a curved form. All articles made in the shape



FIGS. 9,776 and 9,777.—Pexto slip roll formers (forming machine). ***In operation,*** the sheet to be formed is placed between the gripping rolls A and B. The cylinder formed, open latch C, then by means of lever D, raise upper gripping roll A and slip the formed cylinder from the roll A. It will be readily seen that all operations are performed at the crank end of the machine. Rolls B and E, are adjusted with knurled screws, and once adjusted they cannot slip. The roll raising mechanism in these machines is so balanced that the roll A, is easily lifted with a slight pressure on the lever D. The latch C, is released and closed with one movement and is self locking.

of a cylinder and others which are to be bent to a radius greater than 1 in. can be quickly formed in this machine. The machine consists of two geared rolls and one loose roll which serves to bend the work which passes between the first two. The distances between the geared rolls can be regulated by thumb screws. The rear roll can be raised to bend the sheet to a smaller radius.

The general type of all forming machines is similar, though there are

many variations in their mechanism. In principle the forming is done by three rolls. The two front rolls grip the sheet of metal and force is against the rear roll, which bend it around the front upper roll, forming a cylinder. The size of circle that can be formed on a forming machine depends on the nearness of the rear or forming roll to the front upper roll in the machine. The pressure of the gripping rolls, which are the two rolls looking from the front of the machine, is regulated by thumb screws, and the rear or forming roll is regulated in the same manner. Fig. 9,778 shows method of operating a forming machine.

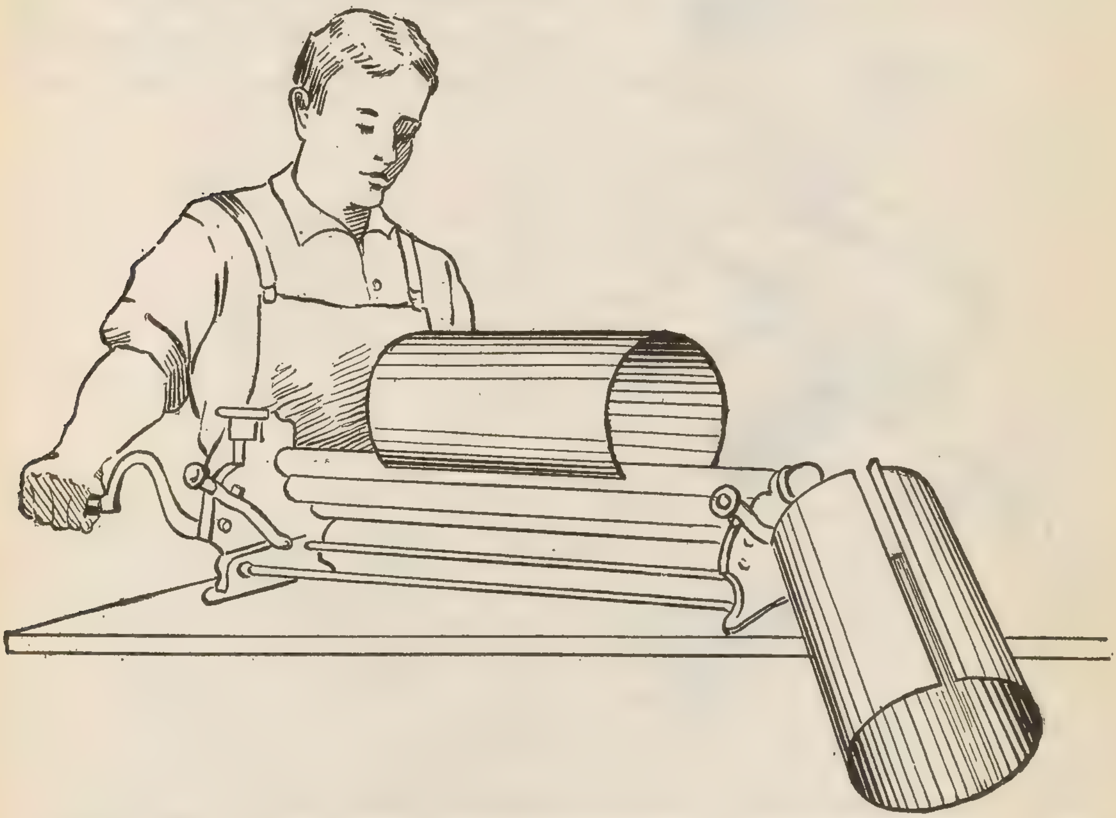
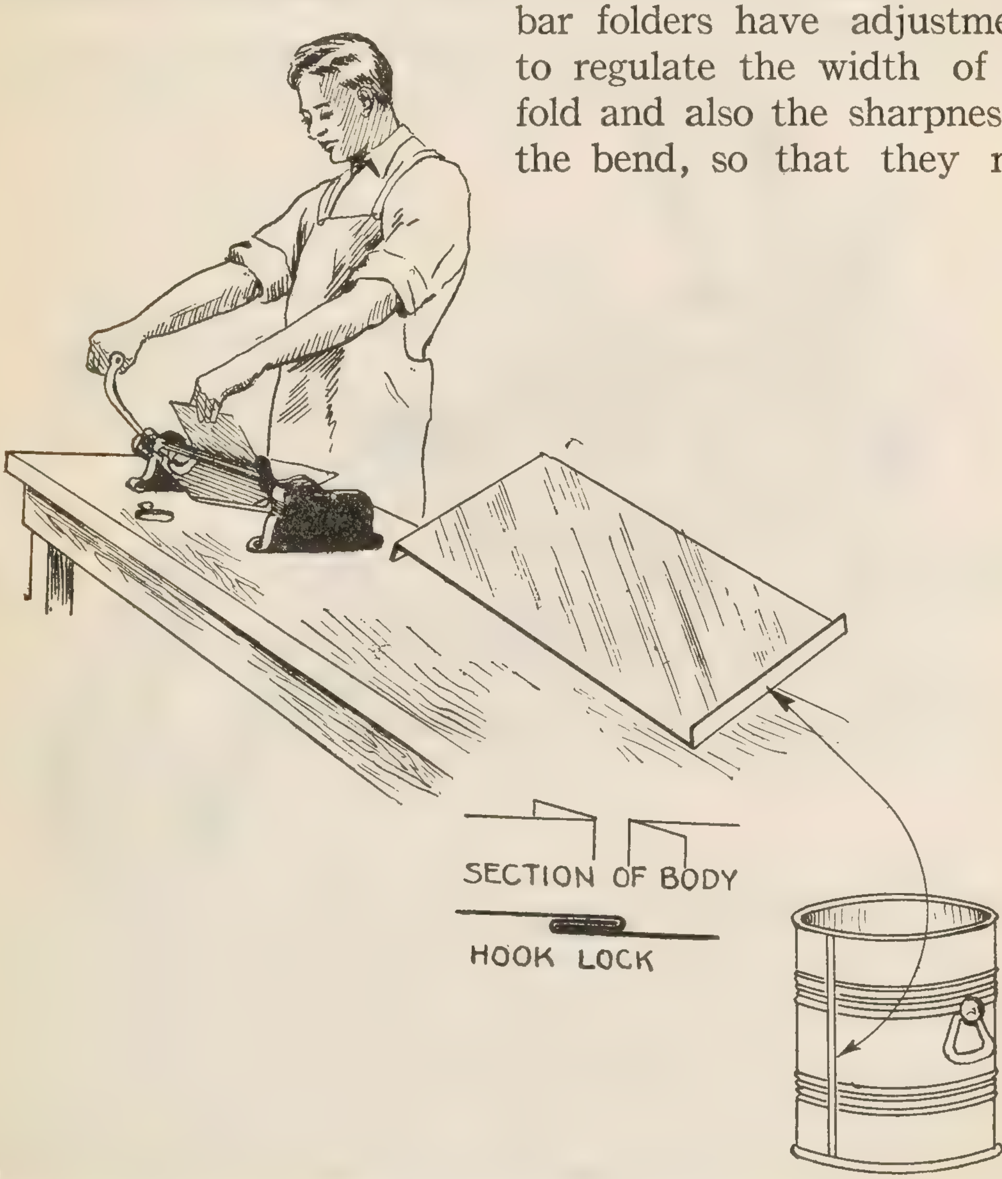


FIG. 9,778.—Forming machine and method of operation. ***In operation,*** the sheet of metal to be formed is inserted from the front of the machine and passed through the two front gripping rolls, securing uniform pressure of the rolls on the material through thumb screws, so that the sheets will ride through the rolls freely. The sheet, in passing through the gripping rolls, will strike the rear or forming roll, if adjusted high enough, thereby forming a circle. If the circle secured in the first experiment should not prove of correct diameter, the lowering of the rear or forming roll will increase the diameter of the cylinder, or by raising the forming roll the diameter of the cylinder will be decreased. In forming cylinders of very small diameters the blank as soon as entered between the gripping rolls must be given enough curvature with the hands by means of bending the material upward, otherwise it will not strike the rear forming roll for the proper shaping of the cylinder to be formed. When the operator becomes accustomed to the forming machine and its mechanism, accurate settings are easily made after the first few trials, according to the judgment used.

Folding Machines.—In order to turn a hem or lock on the edge of a piece of sheet metal some means must be found to hold the metal firmly while the edge is being turned, or the edge may be gripped and the fold turned by moving the piece itself. The bar folder does the latter. These machines will also prepare the edge of sheet metal to receive a wire. All bar folders have adjustments to regulate the width of the fold and also the sharpness of the bend, so that they may



Figs. 9,779 to 9,782.—Folding machine and method of operation, with illustrations of work done by the machine.

also be used to prepare the edge of sheets to receive a wire. It is always necessary to know just how the machine is adjusted before attempting to make a fold or to wire an edge.

Fig. 9,779 shows method of operating a folding machine. The most popular pattern of folding machines are the bar folder, sheet iron folder and pipe folder, the bar folder being the most important.

Grooving Machine.—After a lock seam has been folded on the folder, it should be closed down with a grooved wheel on

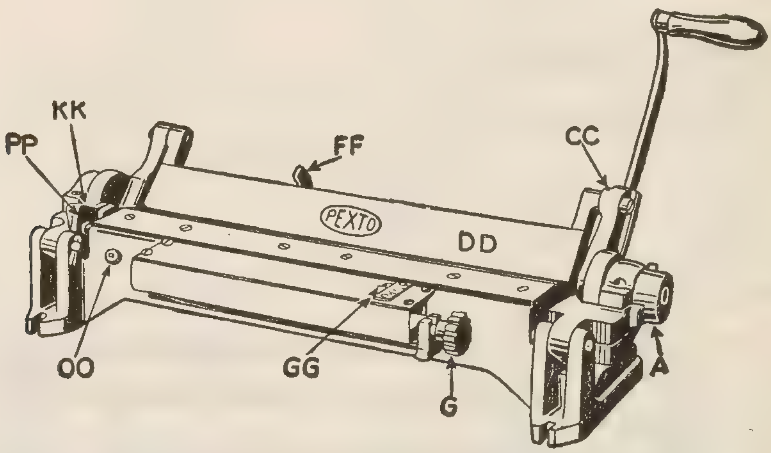
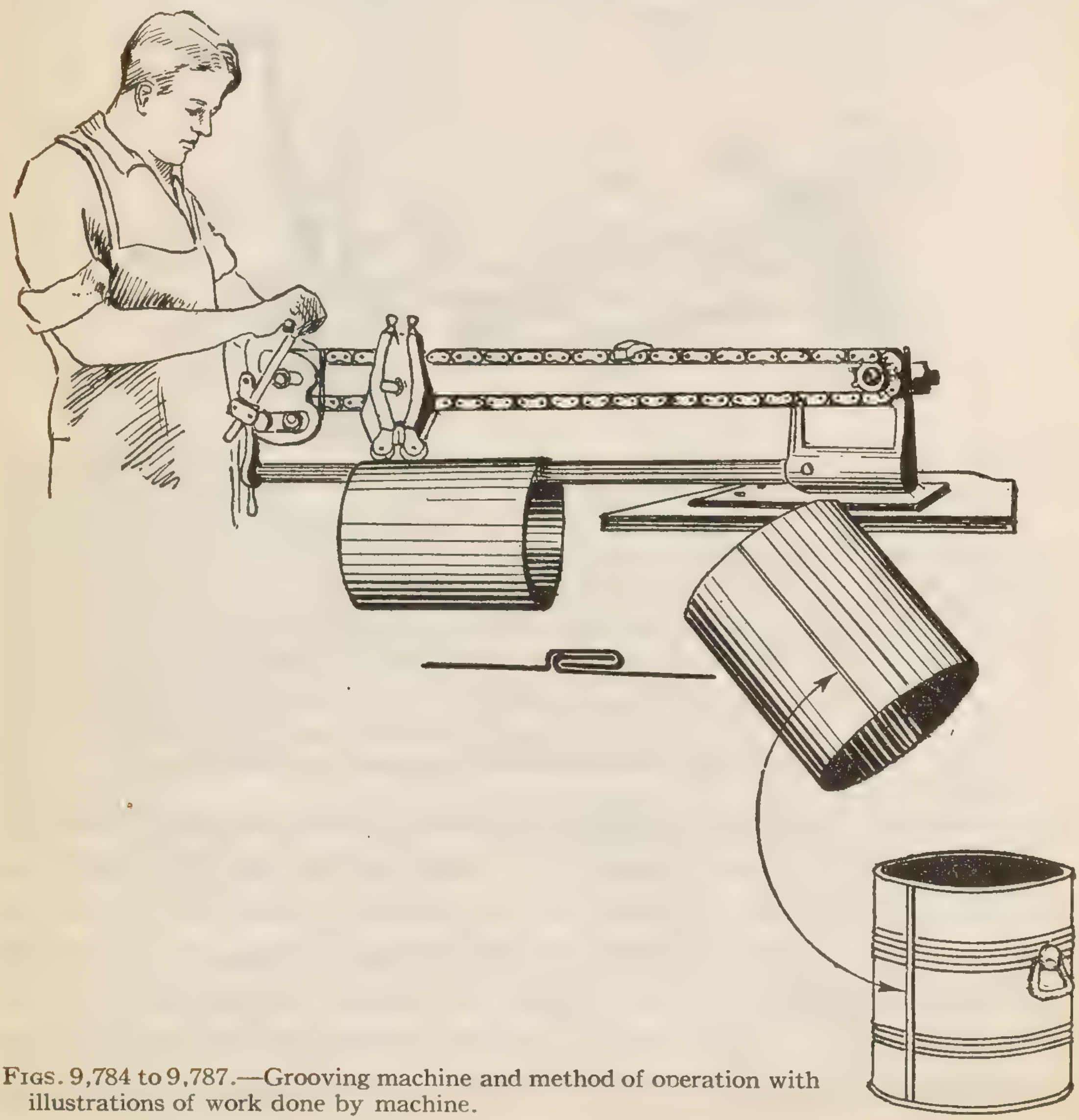


Fig. 9,783.—Pexto "Arrow" bar folder. It is intended for forming the edges of sheet metal at various angles. They will produce closed locks as well as open or round locks for inserting a wire in the flat sheet. Open or round locks for wiring are made by raising the folding bar CC, at right angle. The wing DD, is then adjusted for the size of wire to be used through the setting of wedge FF, that moves to left and right on folding bar. An improvement, consisting of a pin in the frame, prevents the dropping of the wing below the gripping jaw, the wing DD, dropping in a proper position automatically in the process of folding, producing accurate and uniform round locks. Gauge GG, is adjustable, moved by a screw and is adjusted by turning gauge knob G. The width to which the gauge is adjusted is indicated on a graduated brass plate, and after set is firmly secured through lock screw OO. Gauge is so designed that it cannot twist, insuring accurate lock forming. Adjustable stop A, is provided to permit the forming of any desired angle, in addition to regular square and bevel stops KK and PP.

the grooving machine. Hand grooving tools are also used for this, but in all cases where it is possible to use the machine it is better to do so. The grooving rolls are made to fit several widths of seam and the proper roll should be used. A closed lock is first turned on the sheet of metal by the use of the folding machine. The sheet is then rolled into a cylinder by the forming machine, when the corresponding edges, as

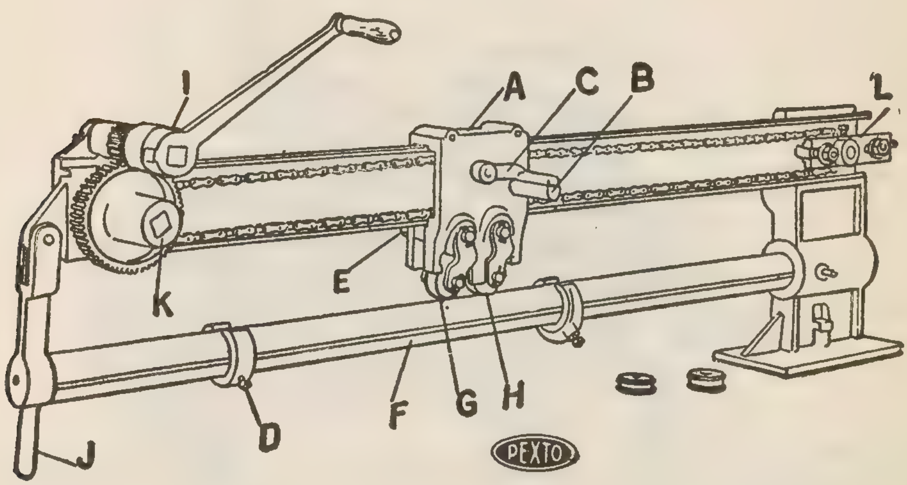
prepared in the cylinder are snapped together and laid on the grooving horn in the grooving machine. The grooving rolls in the grooving machine run over the seam lengthwise, effecting an operation called "grooving" or "seam closing" and completing the lock.

Fig. 9,784 shows the grooving operation and figs. 9,786 and 9,787 the appearance of lock before and after grooving.



FIGS. 9,784 to 9,787.—Grooving machine and method of operation with illustrations of work done by machine.

Burring Machine.—This machine is used for turning an edge on cylinders of metal or on discs such as can bottoms. In preparing vessels for double seaming, a burr is first turned at a right angle on the body and then one of the same width on the edge of the bottom. This last operation is quite difficult and takes considerable practice.



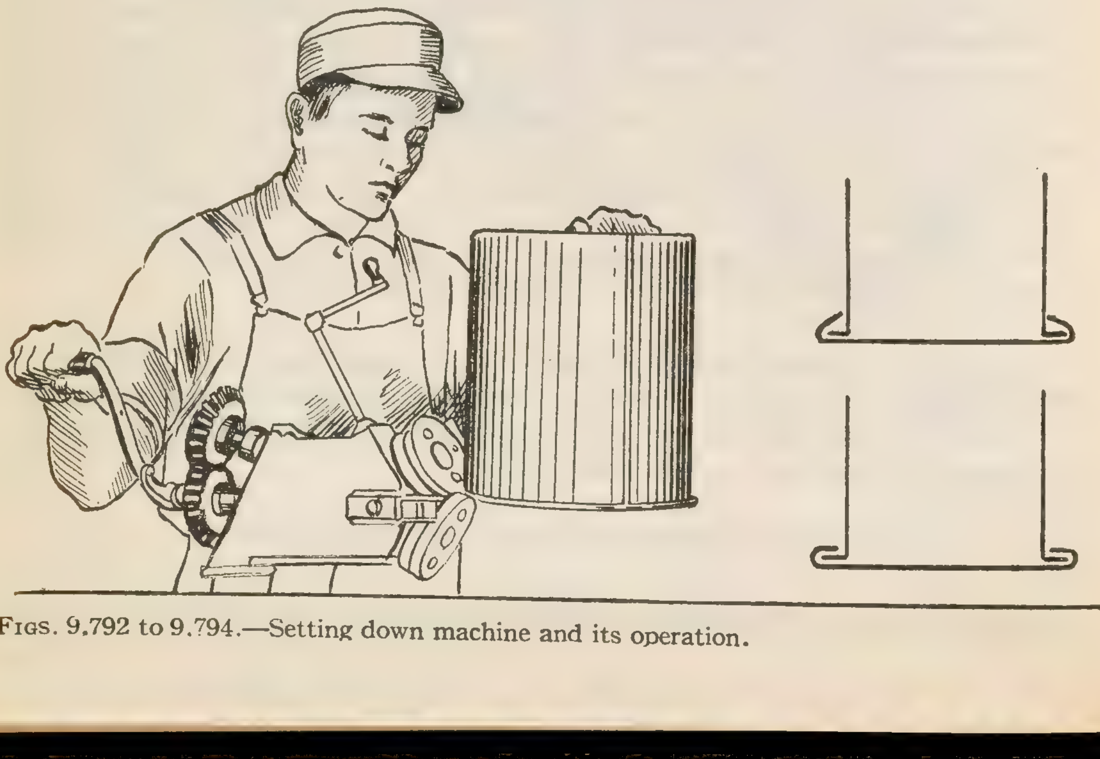
FIGS. 9,788 to 9,790.—Pexto heavy rapid groover. ***In construction,*** A, is the grooving carriage that moves on a chain through gears; L, take up attachment, if the chain should stretch after a long and constant use; C, release lever, disengaging the carriage from chain. When so disengaged the carriage A, can be worked backward and forward by the handle B, for lightning grooving on light material. The position of hand crank I, offers a geared machine. Fitting the crank I, in the large gear K, the machine becomes direct acting for increased speed on light work. Pressure of the grooving roll G, and flattening roll H, is secured through eccentrics and which are quickly and easily adjusted through a turn of knobs E. The flattening roll H, runs idle on the outward run and the grooving roll G, idle on the backward run. The two rolls do not press the seam at the same time. Lower horn F, is reversible, so that either the flat surface or one of the grooves which is planed into the horn can be turned upward, permitting the locating of seams on the inside or the outside of the work. The stop D, is steel and prevents work slipping while the grooving is taking place.

In using the burring machine, it should be noted that only a narrow burr about ⅛ in. wide can be turned. The burring machine is the hardest machine for beginners to use. The pupil should avoid spoiling good material until he has had careful instruction.

Fig. 9,791 shows method of operating a burring machine.

Setting Down Machine.—This machine is used to close the

FIG. 9,791.—Burring machine and method of turning a burr. This is a difficult operation to master but practice will produce uniform flanges on sheet metal bodies and prepares the burr for bottoms preparatory to setting down and double seaming.



FIGS. 9,792 to 9,794.—Setting down machine and its operation.

seams left by the burring machine making ready the seams for double seaming. The machine is very simple and may be turned in either direction. It has no adjustments except for thickness of material.

Figs. 9,792 to 9,794 illustrate operation of a setting down machine. *In*

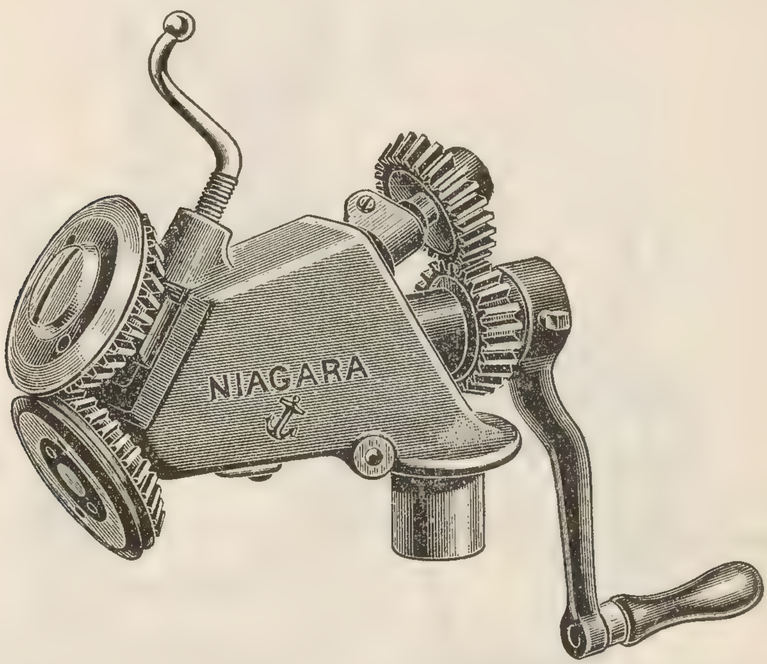
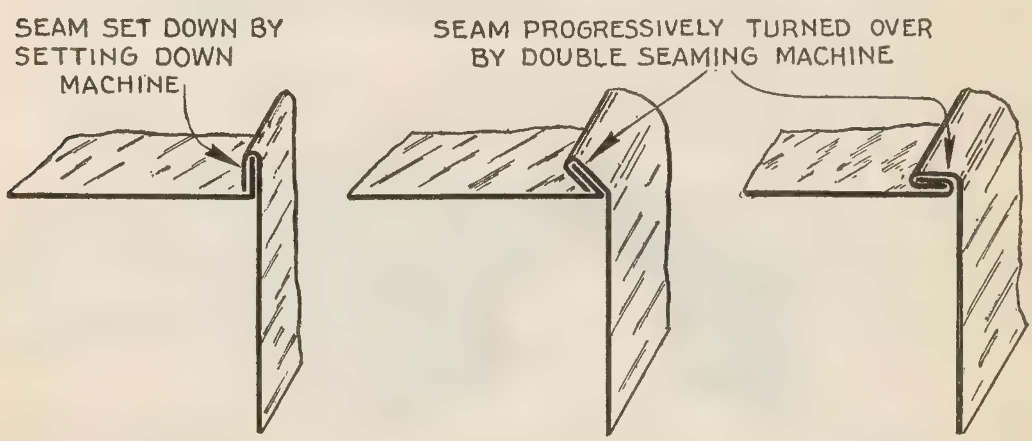


Fig. 9,795.—Niagara setting down machine with inclined faces. This machine turns down and compresses the flange of the bottom on to the flange at the end of the body, thereby forming a joint which can be doubled over afterwards with a double seaming machine.



Figs. 9,796 to 9,798.—Progressive operations of setting down machine and double seaming machine in forming a double seam.

operation, the vessel is held bottom upward and the edge A, of the bottom runs between two rolls, when the corresponding edges are pressed or closed tight ready for double seaming as shown at B.

Double Seaming Machine.—After the seams have been set

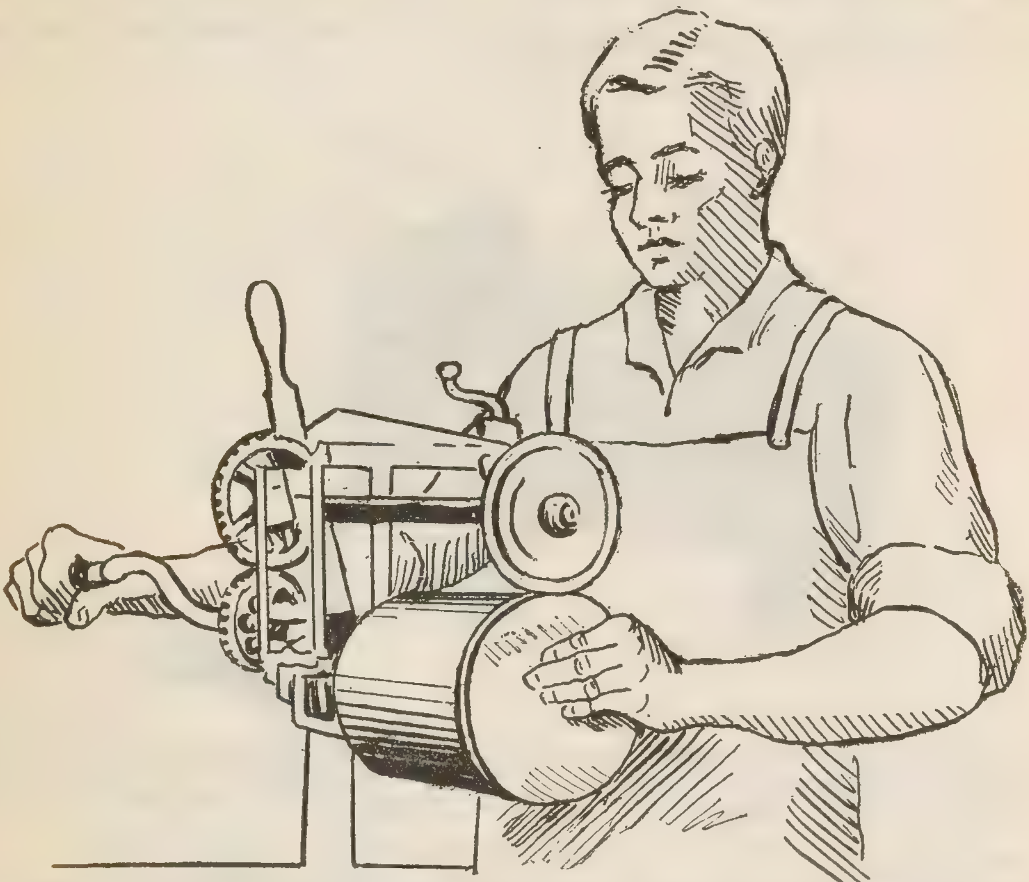
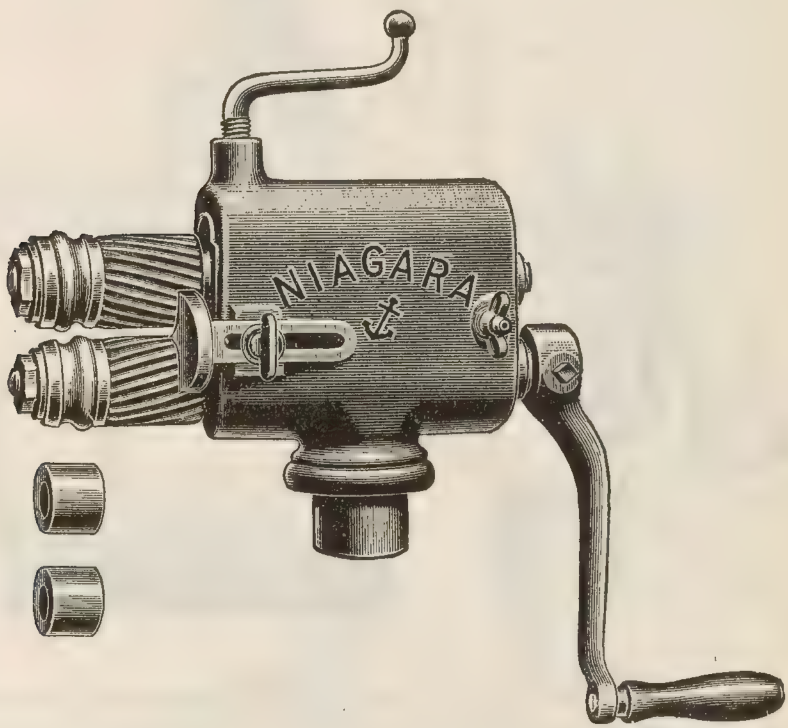


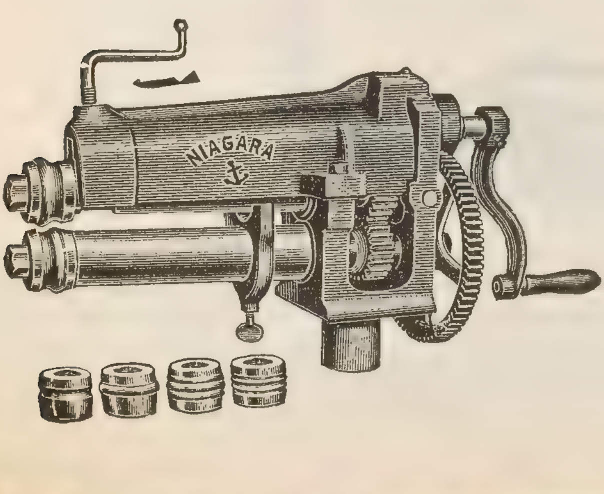
FIG. 9,799.—Double seaming machine and its operation. Fig. 9,796 shows a seam as set down with a setting down machine, and figs. 9,797 and 9,798, the progressive turning over of the seam with the double seaming machine making a tight joint.

FIG. 9,800.—Niagara hand roofing double seamer. The standing seam of sheet metal roofing finished on these blocks after the edges were turned with tongs.

down properly with the setting down machine the flange as left must be turned against the body of the vessel. This double seaming operation can be effected with the double seaming stake and mallet. A double seaming machine will double seam the work with a greater degree of neatness and accuracy



FIGS. 9,801 to 9,803.—Niagara crimper and beader. This machine is not backgeared, being intended for quick operation on light work. It is adjustable for depth of crimp and bead.



FIGS. 9,804 to 9,808.—Niagara beading machine and rolls. This machine is used for ornamenting and stiffening tinware and other sheet metal goods by forming beads corresponding with the shape of the rolls.

and more often saves the loss of a good job by unattractive stake double seaming.

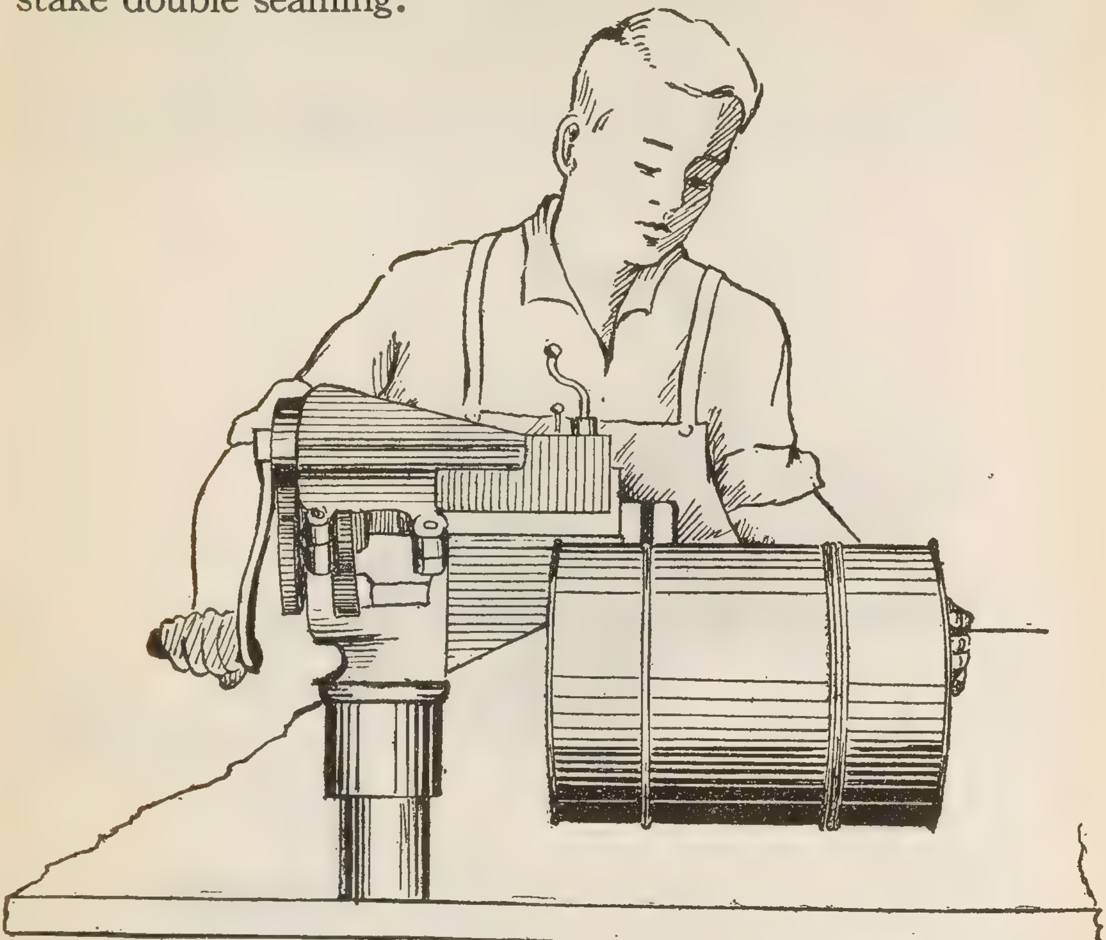
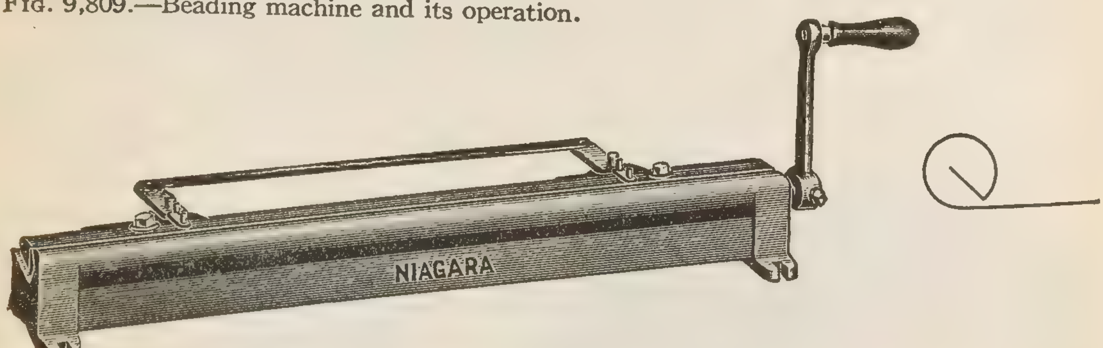


FIG. 9,809.—Beading machine and its operation.



FIGS. 9,810 and 9,811.—Niagara adjustable gutter beader and example of work. ***It is intended*** to round and stiffen the edge of gutter by forming a so called bead as shown in fig. 9,811. Rods from ⅜ to ¾ in. diameter can be used in the frame of adjustable gutter beaders. The two jaws can be spread apart to facilitate removing the work and rod. Stops fix the workng position of the moveable jaw.

Fig. 9,799 illustrates the operation of a double seaming machine.

Beading Machine.—This machine is a very simple one to operate. It is furnished with a series of rolls of different shapes. The impression made in the bodies of vessels will correspond with the shape of bead in the rolls used. Making these impressions is called beading which serves to ornament and strengthen the bodies of vessels or on any other work where the machine is applied.

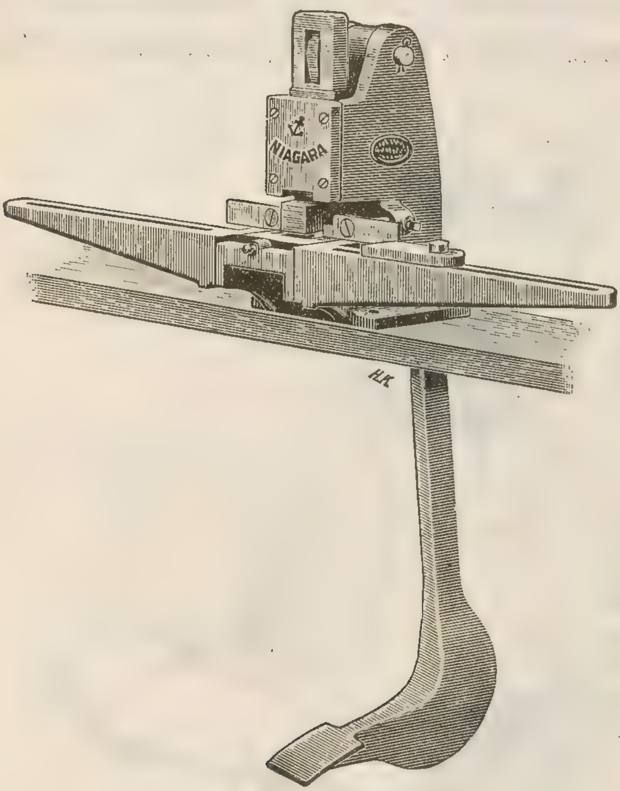


FIG. 9,812.—Niagara notching machine foı notching sheet metal for wiring and grooving, for cutting corner and hinge notches, etc. The rectangular die is suitable for notches up to 1½ ins. wide and 2 ins. deep. Adjustable side and back gauges are provided, and several thicknesses of light tin can be cut at the same time.

Fig. 9,806 illustrates the operation of a beading machine.

Crimping and Beading Machine.—The crimp and bead so much in evidence on the edge of the common stove pipe are made with this machine.

Crimping and beading machines are intended to facilitate the making and puttıng together of sheet iron pipe of different diameters, by contracting

the edge of the pipe so that one joint of pipe will enter another. In putting together the pipe the ogee bead next to the crimp prevents the joints slipping beyond the impression made with the beading rolls.

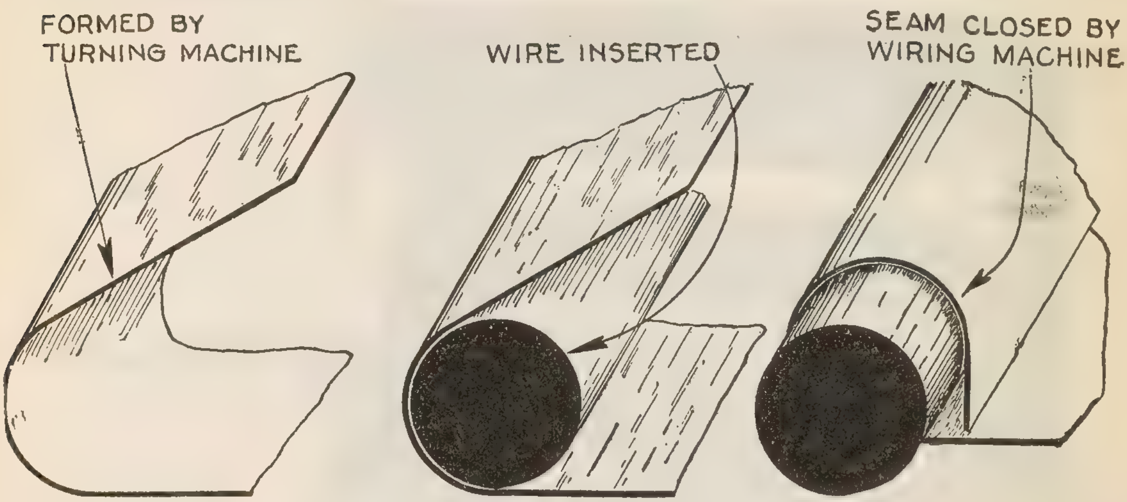
Turning Machine.—This machine is used to form a rounded edge into which a wire is inserted, the edge being closed by a wiring machine. The operation of a turning machine is shown

Fig. 9,813.—Turning machine and its operation.

in fig. 9,813 and the shape of the edge formed by the machine in fig. 9,814.

Wiring Machine.—This machine finishes the operation begun

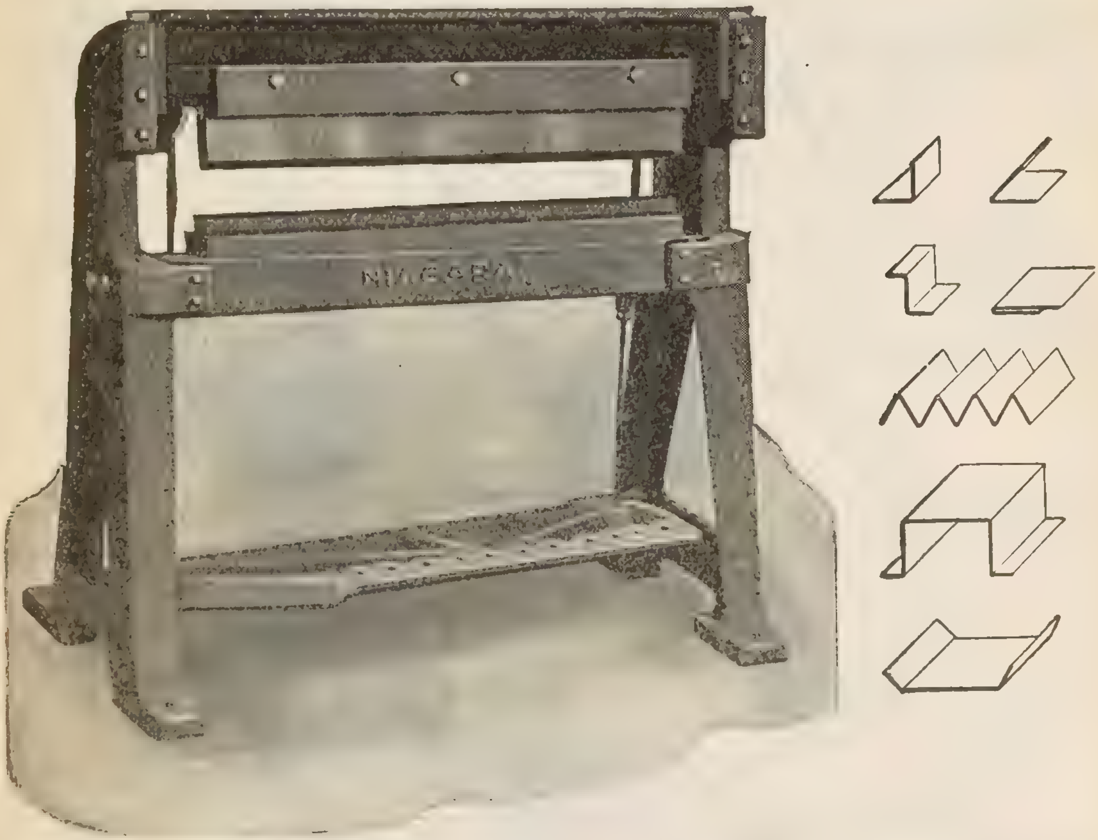
by the turning machine. Depending upon the shape of the work, the seals to receive the wire are sometimes prepared on the folder or brake instead of the turning machine.



FIGS. 9,814 to 9,816.—Operations in making a wired seam with turning and wiring machines.

FIG. 9,817.—Wiring machine and its operation.

Brake.—This machine has a wider range of usefulness than the folder. It may be used to turn hems or folds and to make bends at all angles up to nearly 180 deg., and at any distance



Figs. 9,818 to 9,825.—Niagara foot brake and various bends produced by same. This machine is designed for dies or blades intended to perform straight bending operations on light sheets.

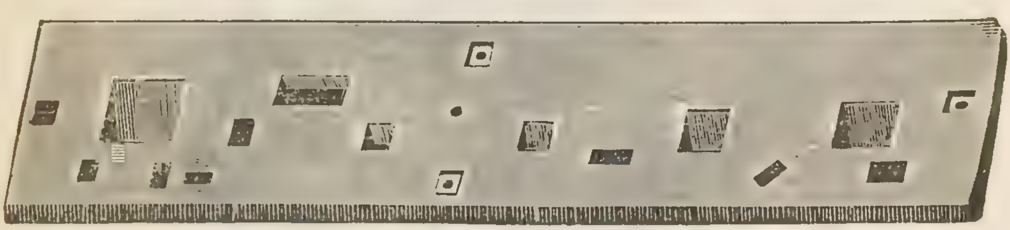
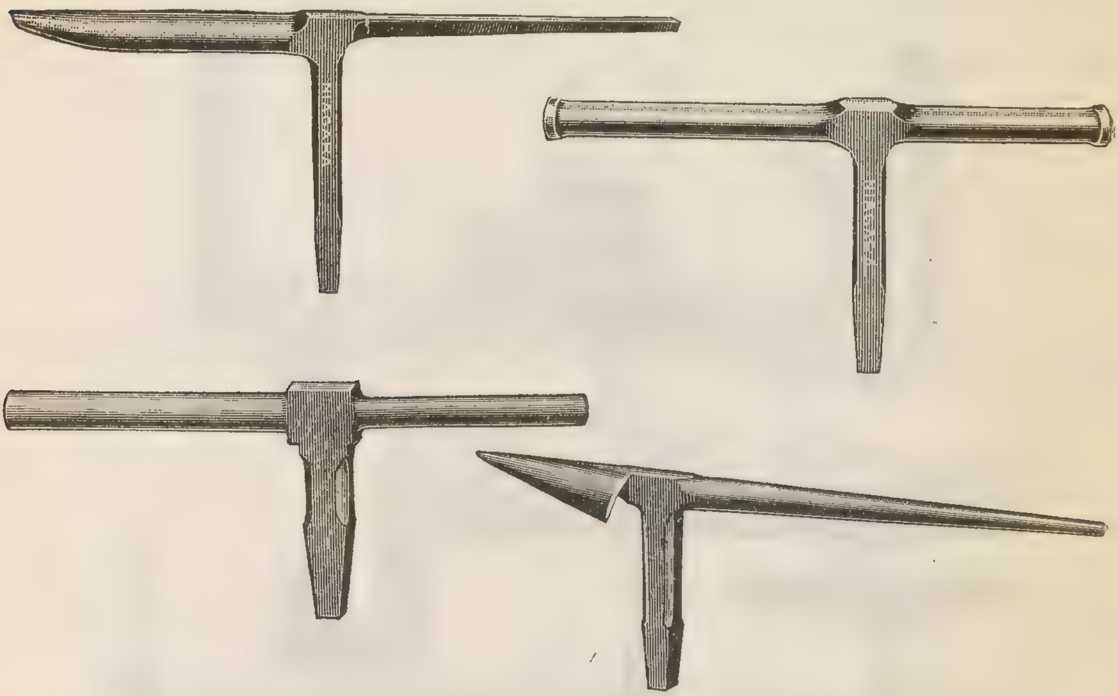


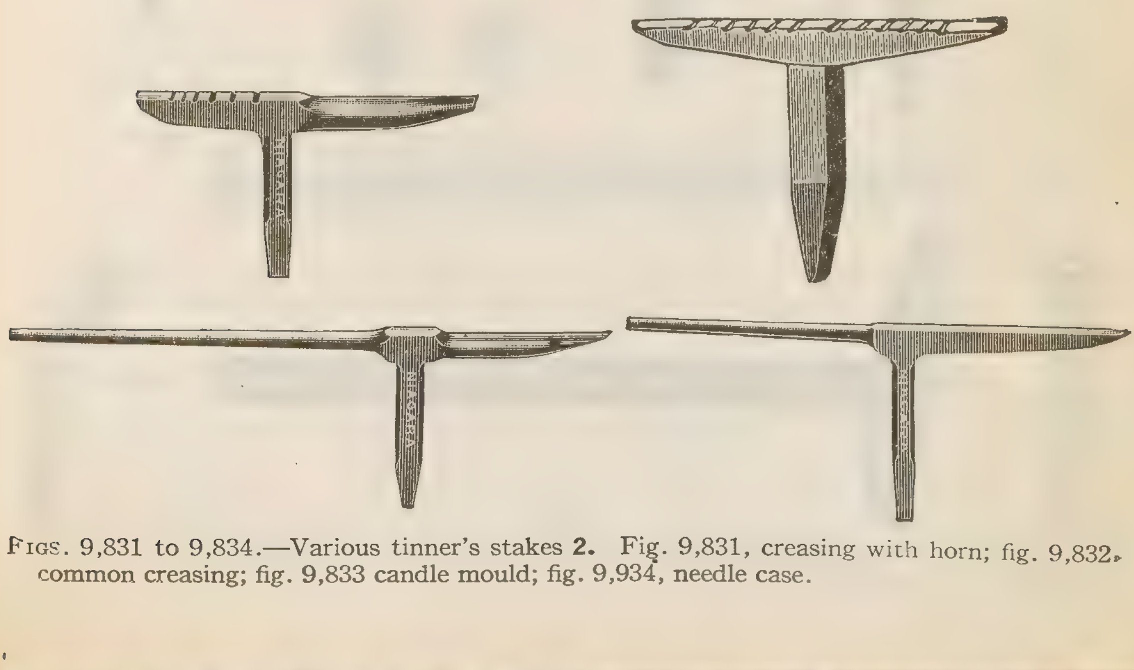
Fig. 9,826.—Niagara bench plate for holding stakes and bench shears.

from the edge. It is supplied with moulds that permit the forming of moulded shapes to almost any pattern for cornices. These machines in their lengths up to 8 ft. are in common

use. Brakes have a capacity for forming locks and angles in a wide range of sizes and of unusually large lengths. The folding

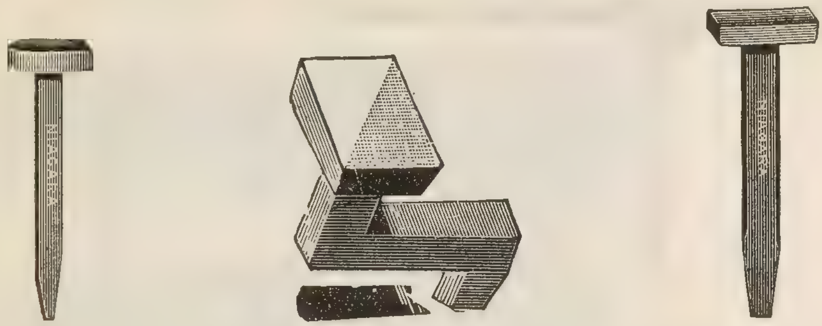


Figs. 9,827 to 9,830.—Various tinner's stakes **1.** Fig. 9,827, beakhorn; fig. 9,828, double seaming; fig. 9,829, conductor; fig. 9,830, blowhorn.

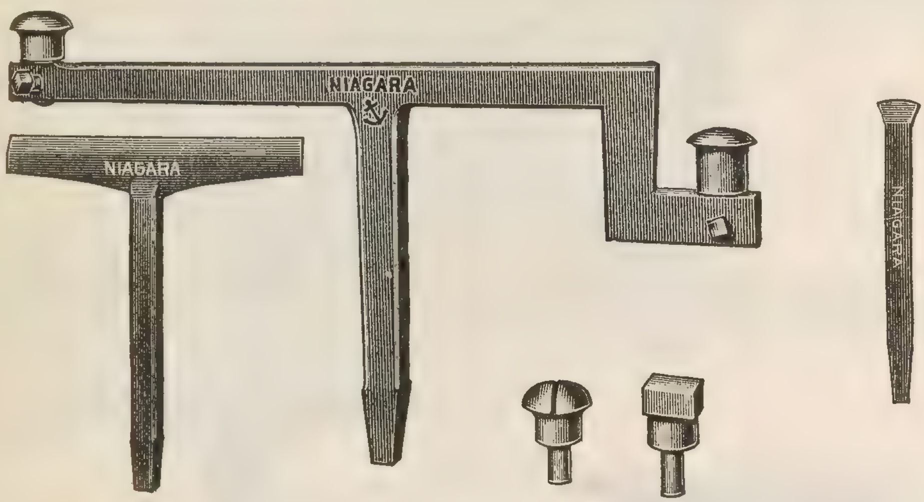


Figs. 9,831 to 9,834.—Various tinner's stakes **2.** Fig. 9,831, creasing with horn; fig. 9,832, common creasing; fig. 9,833 candle mould; fig. 9,934, needle case.

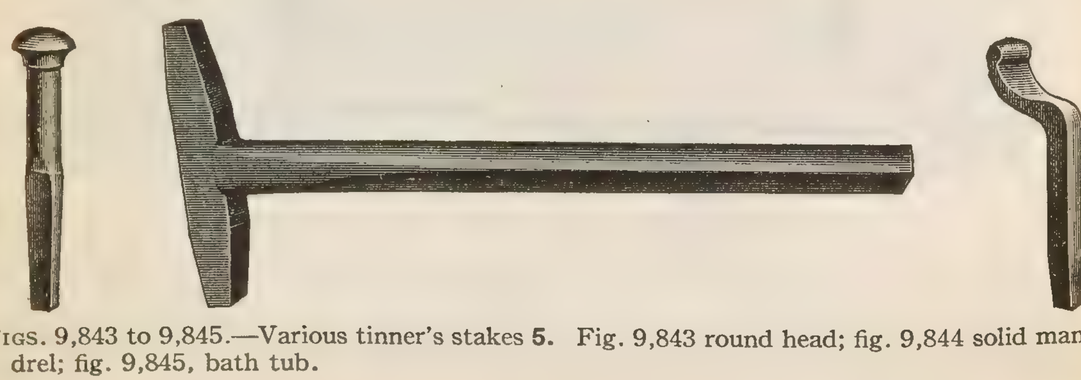
machine can only form a lock or edge as wide as the depth of the jaw in the machine will permit, whereas, the brake



FIGS. 9,835 to 9,837.—Various tinner's stakes **3.** Fig. 9,835, common square; fig. 9,836, bevel edge; fig. 9,837 coppersmith's square.



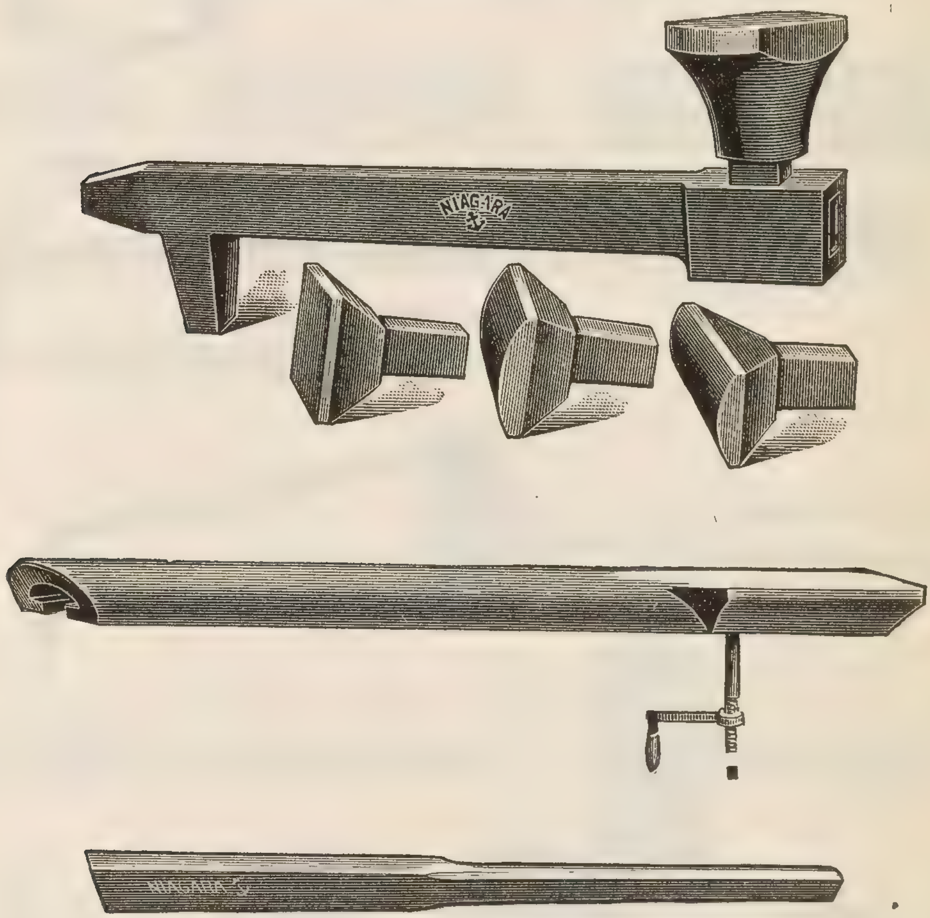
FIGS. 9,838 to 9,842.—Various tinner's stakes **4.** Figs. 9,838 to 9,840 tea kettle with four heads; fig. 9,841, hatchet; fig. 9,842, bottom.



FIGS. 9,843 to 9,845.—Various tinner's stakes **5.** Fig. 9,843 round head; fig. 9,844 solid mandrel; fig. 9,845, bath tub.

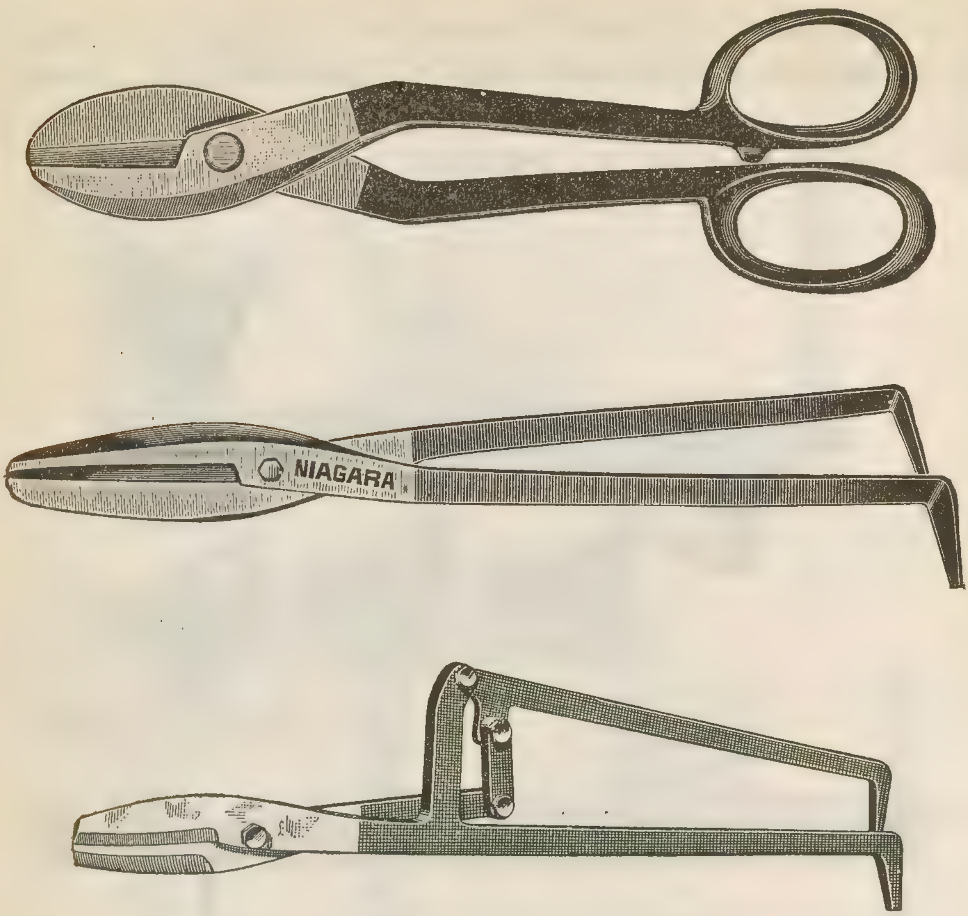
allows the sheet of metal that is to be edged or formed to pass through the jaws from front to back without obstruction.

Fig. 9,818 shows a typical foot brake, and figs. 9,819 to 9,825 some of the shapes produced by this machine.

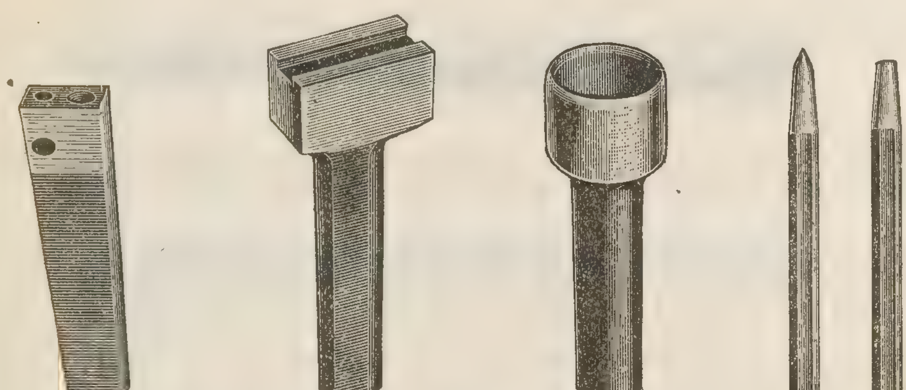


FIGS. 9,846 to 9,851.—Various tinner's stakes 6. Figs. 9,846 to 9,849. double seaming stake with four heads; fig. 9,850, hollow mandrel; fig. 9,851 solid mandrel.

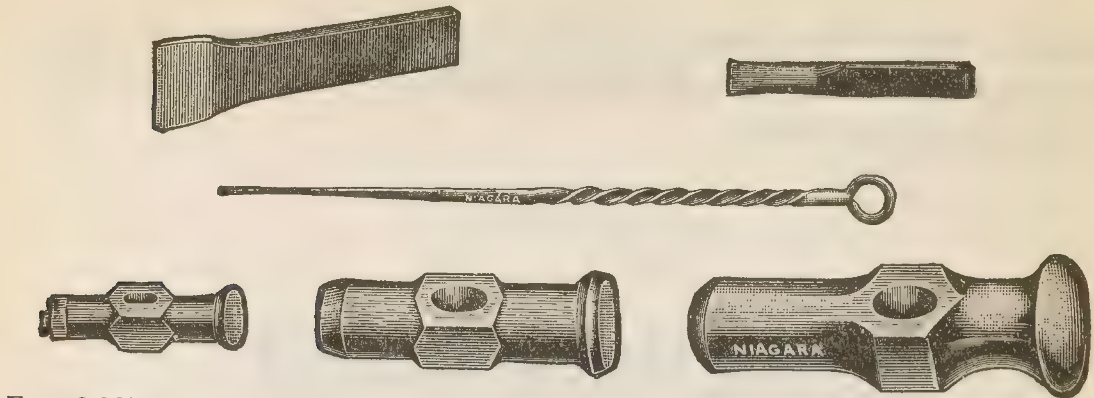
Stakes.—Sheet metal is in many instances shaped by being bent over anvils of peculiar forms known as *stakes*. These fit into holes cut in the bench, the stakes being held rigid by a bench plate as shown in fig. 9,826. The plate is fastened to the bench. The plate is also used to hold bench shears. There is



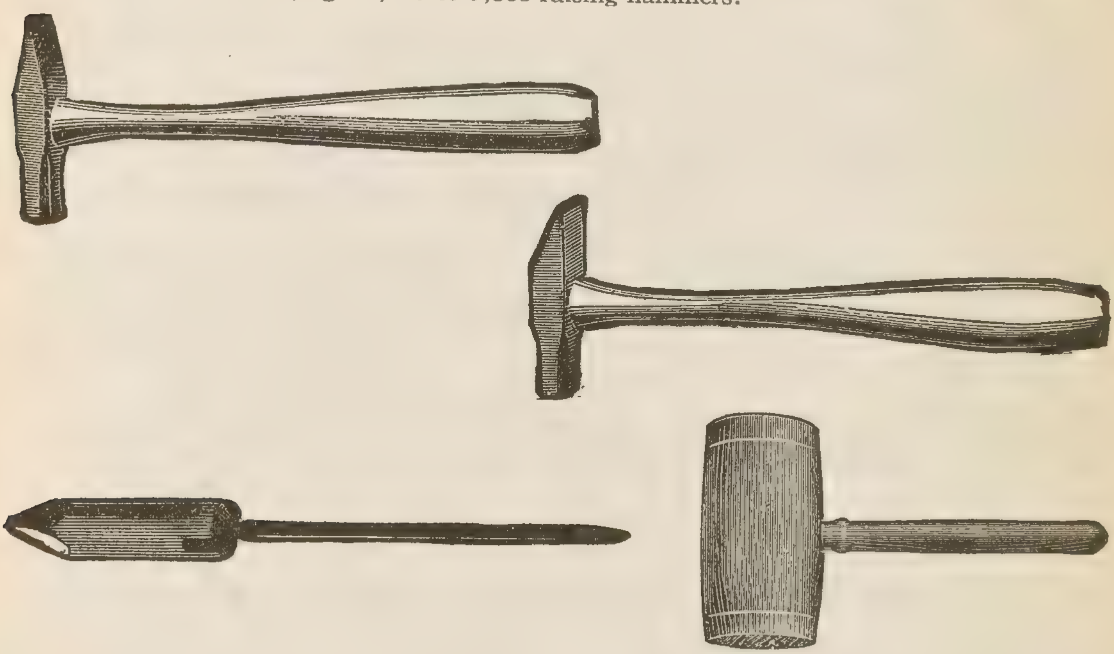
FIGS. 9,852 to 9,854.—Tinner's hand tools **1**. Fig. 9,852, heavy snips; fig. 9,853, bench shears; fig. 9,854 compound bench shears.



FIGS. 9,855 to 9,859.—Tinner's hand tools **2**. Fig. 9,855, rivet set and headers; fig. 8,856, grooving tool; fig. 9,857, hollow punch; figs. 98,58 and 9,859. solid punches.



FIGS. 9,860 to 9,865.—Tinner's hand tools **3.** Fig. 9,860, wire chisel; fig. **9,861,** lantern chisel; fig. 9,862, scratch awl; figs. 9,863 to 9,865 raising hammers.



FIGS. 9,866 to 9,869.—Tinners' hand tools **4.** Fig. 9,866, riveting hammer; fig. 9,867 setting hammer; fig. 9,868, soldering copper; fig. 9,869 mallet.

FIG. 9,870.—Steel circumference rule. This rule gives the circumference of circles by simply measuring the diameters. The top edge is a rule graduated in sixteenths inch. The bottom indicates the circumference of circles, which are equal in diameter to the measurement given directly opposite on the other edge. The reverse side gives useful table of measurements.

a great variety of stakes as shown in the accompanying illustrations and the use of each will be inferred by its shape without a detailed description.

CHAPTER 151

Blacksmithing

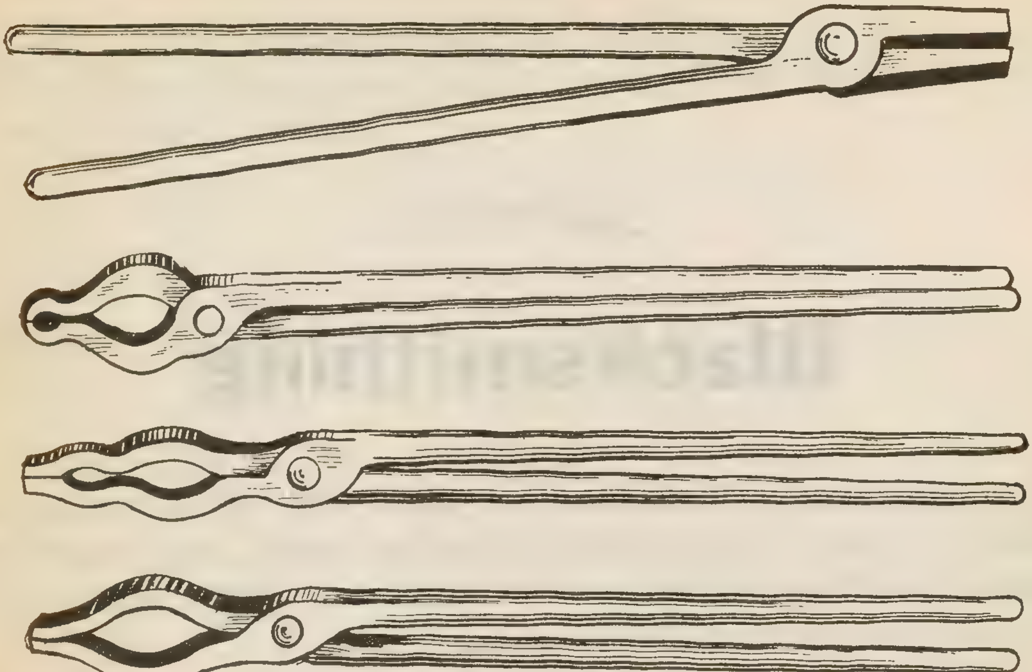
By definition, a blacksmith is a smith who works in or welds wrought iron, as by beating upon an anvil, and makes or shapes small utensils or parts of machines, shoes horses, etc., one who forges or welds iron on an anvil.

Formerly a blacksmith was a smith who worked in black metal or iron, as distinguished from a white smith, who worked on white metal or tin.

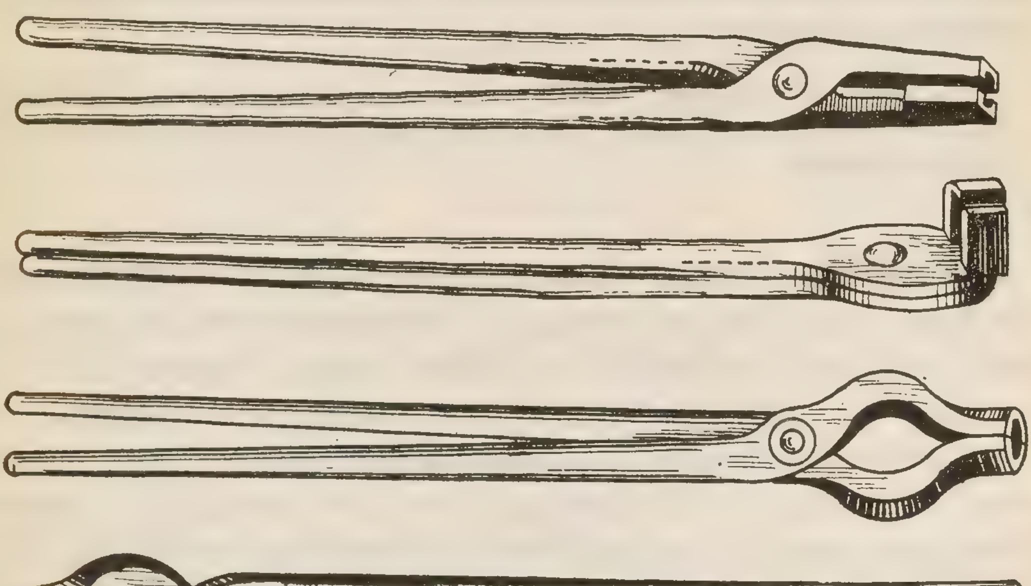
The subject of forging, which forms a large part of the blacksmith's work is taken up in Chapter 153, which may be regarded as a continuation of this Chapter.

Blacksmith's Tools.—The sections of metal worked by the blacksmith are few and simple. The sections of iron and steel dealt with by the smith are either round, square or a rectangular bar; hence no complicated tools are necessary. The only cutting tools used by the blacksmith are those actually employed to sever the forging from the stock or to remove extraneous metal, the chief art of smithing consisting in reducing the sectional bar to the desired form or drawing it out.

NOTE.—***Originally*** the term ***Smith*** was applied to anyone who made anything. The large family of Smiths are honorably descended from people who in early times had accomplished something notable.



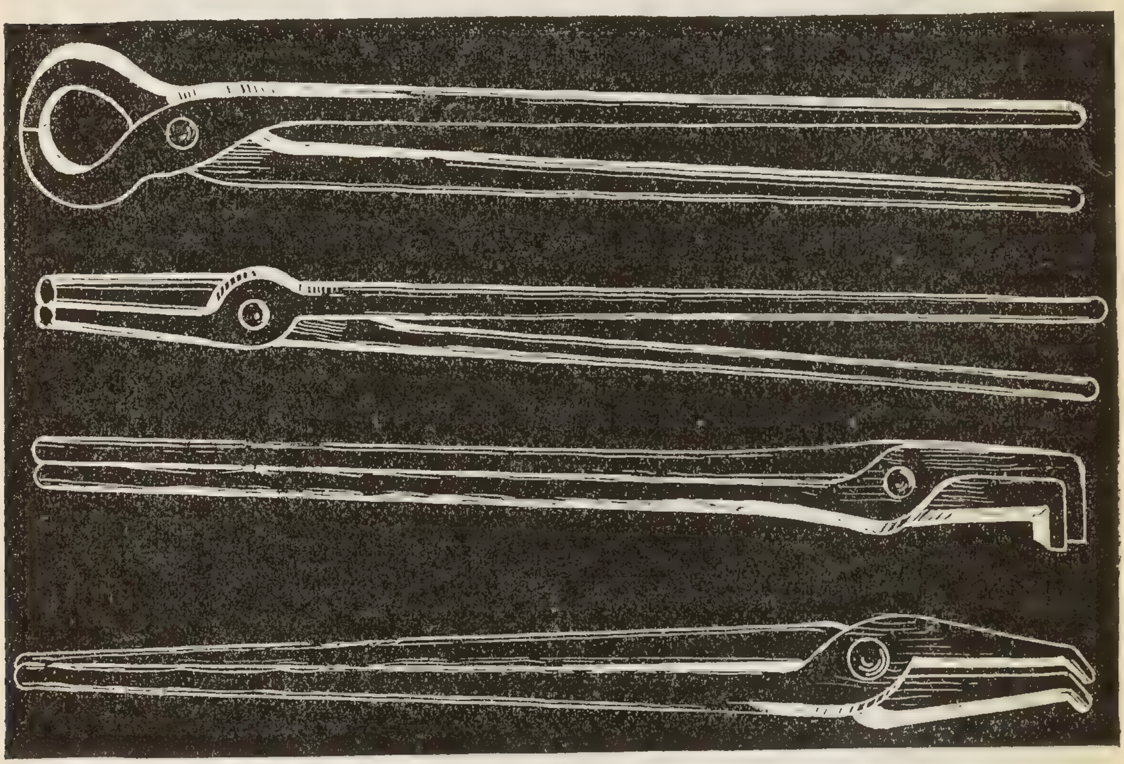
FIGS. 9,871 to 9,874.—Various tongs **1**. Fig. 9,871, straight lip; fig. 9,872, single pick up; fig. 9,873, double pick up; fig. 9,874, rivet.



FIGS. 9,875 to 9,878.—Various tongs **2**. Fig. 9,875, lathe tool; fig. 9,876, pick; fig. 9,877, curved lip or bolt; fluted jaw; 9,878, gad.

Tongs of various shapes are used to hold the iron bars which are being operated upon. The anvil and its attachments are important tools which are used in nearly all operations.

Tongs.—Next to the anvil and hammer in importance are the tongs, of which there is a great variety. Tongs are used

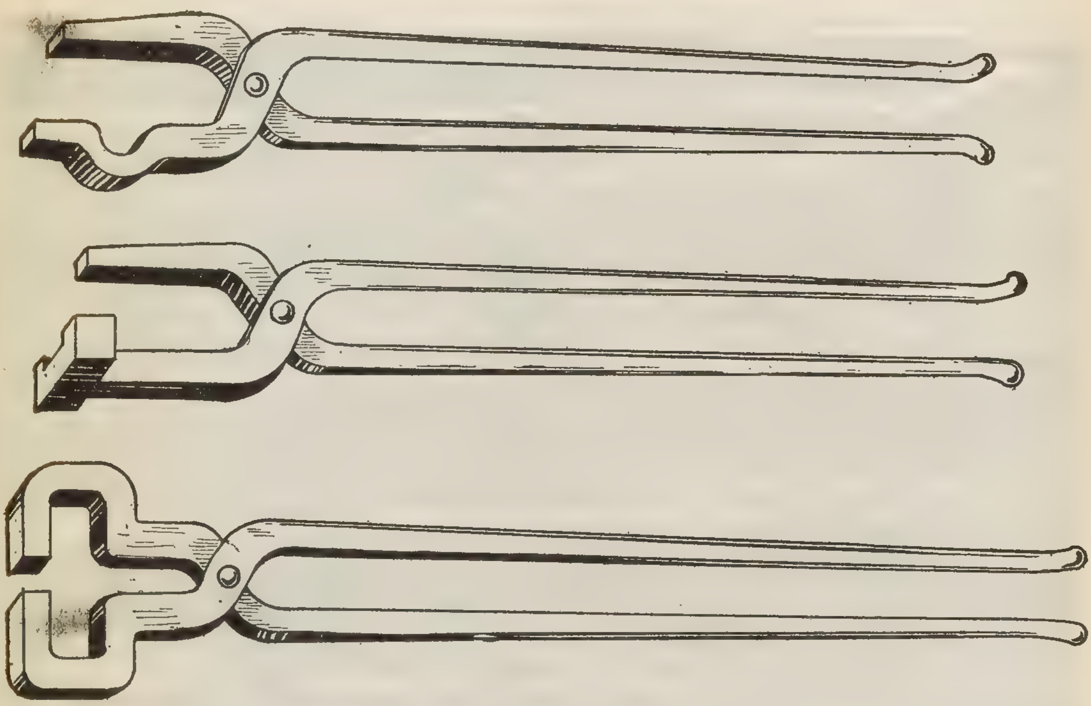


Figs. 9,879 to 9,882.—Various tongs **3.** Fig. 9,879, bolt; fig. 9,880, round jaw; fig. 9,881, angle jaw; fig. 9,882, clip.

for holding metal that is at too high a temperature to be held in the bare hands; for placing iron in and removing it from the fire, and work of a similar character. As the hand should be free to manipulate and turn the metal, the tongs are held in position by a link driven on over the handles. The elasticity of the handles serves to hold the work securely.

Fig. 9,871 represents the simplest form of tongs. These are known as flat tongs from the shape of the jaws. They are used for holding flat pieces of metal, and vary in size according to the work in hand.

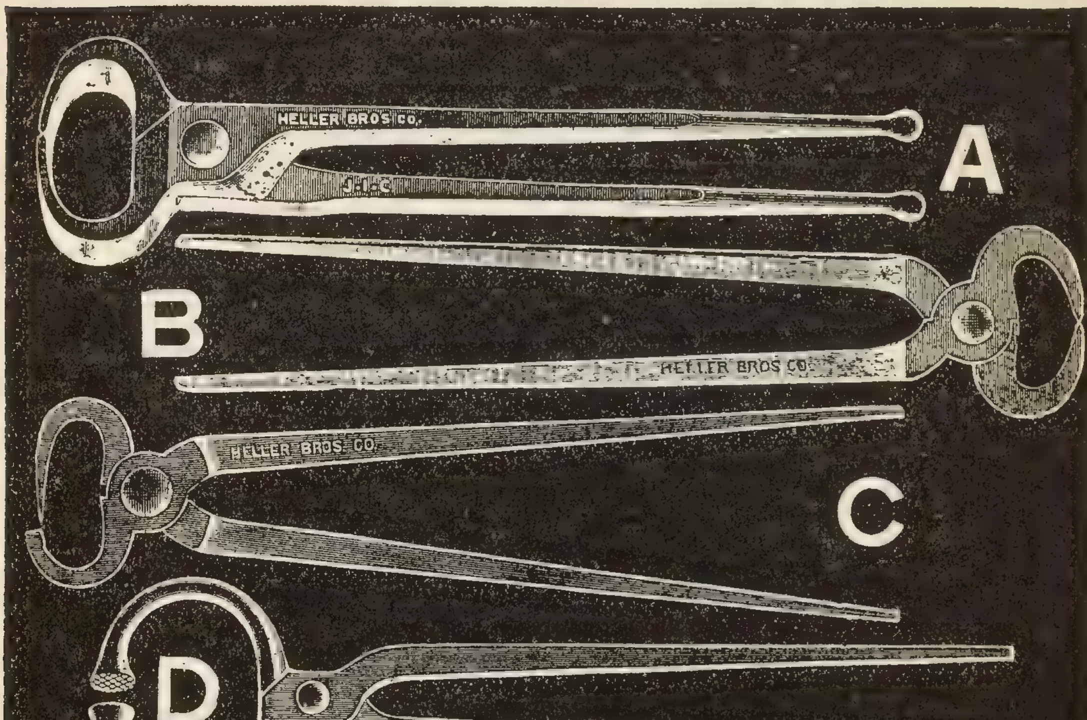
Figs. 9,872 and 9;873 show single and double pick up tongs. These are used for picking up hot pieces of metal that may have fallen upon the floor.



Figs. 9,883 to 9,885.—Various tongs **4.** Fig. 9,883 modified pincer; fig. 9,884, box; fig. 9,885, single goose neck.

They are usually light and have long handles so that objects on the ground may be reached without stooping.

Round bit tongs are illustrated in fig. 9,871. The jaws are concave and are suited for holding cylindrical objects. Tongs of this kind are frequently made of great strength and weight and are adapted to the handling of heavy shafts and axles. Similar tongs are used for holding square pieces. In such, the jaws have a rectangular recess instead of a circular one. A square piece can thus be held more securely by gripping on the corners than when it is seized on the flat surface.



FIGS. 9,886 to 9,893.—Various tongs 5. **A,** farrier's pincer; **B,** cutting nipper; **C,** hoop parer; **D,** hoop tester; **E,** clincher; **F,** horse shoe nail puller or cotter pin puller; **G,** V shape; **H,** rivet.

Anvil.—By definition, an anvil is a heavy block of iron and steel upon the surfaces of which the smith beats heated plastic metal to the desired shape. Its construction is shown in fig. 9,895. As here shown there are several well defined parts. These parts are

1. Face
2. Rounded corner
3. Hardy pole
4. Punch or slug hole
5. Cutting block
6. Horn
7. Heel
8. Body
9. Feet

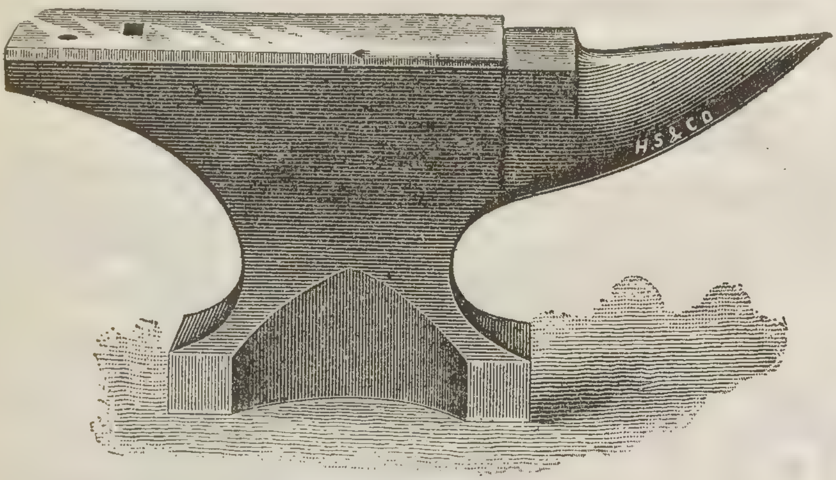


FIG. 9,894.—Typical blacksmith's anvil with first class construction, it is made of best wrought iron and faced with best crucible cast steel. Top and bottom are each one solid piece and welded at waist.

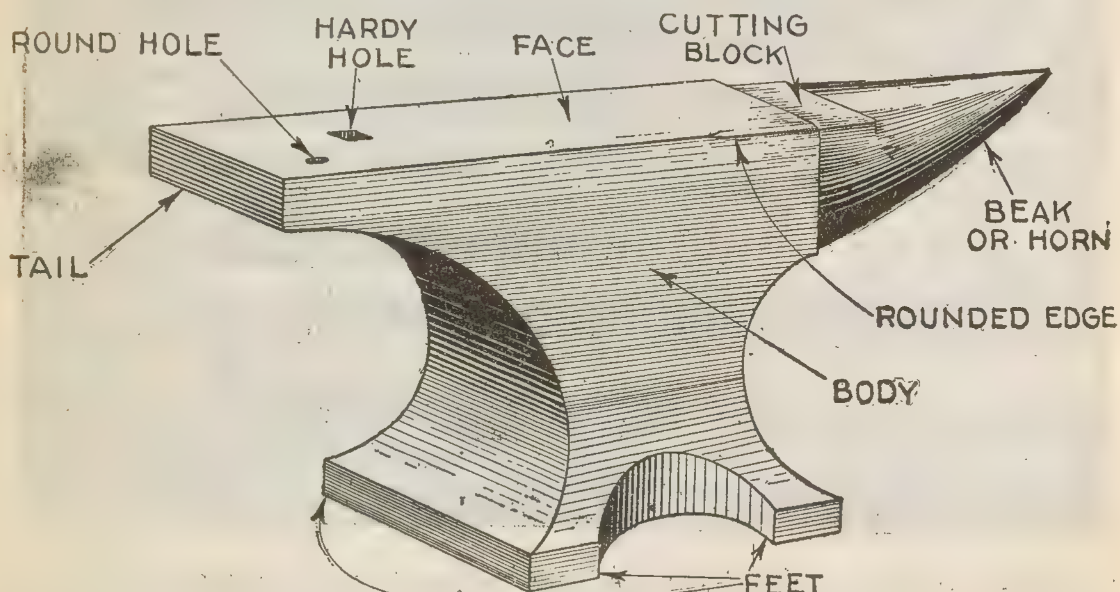


FIG. 9,895.—Ordinary blacksmith's anvil with names of parts.

The face of a good anvil is of hardened and tempered steel. The smith is very particular about its condition. Care must be exercised to prevent cutting into the face of the anvil or marring it with the edge of the sledge or hammer.

The edges of the anvil should not be chipped from careless operations. The rounded corner provides a working surface of very short radius.

The hardy hole is a square opening in the face of the anvil at the heel end, into which the tangs of the anvil tools fit.

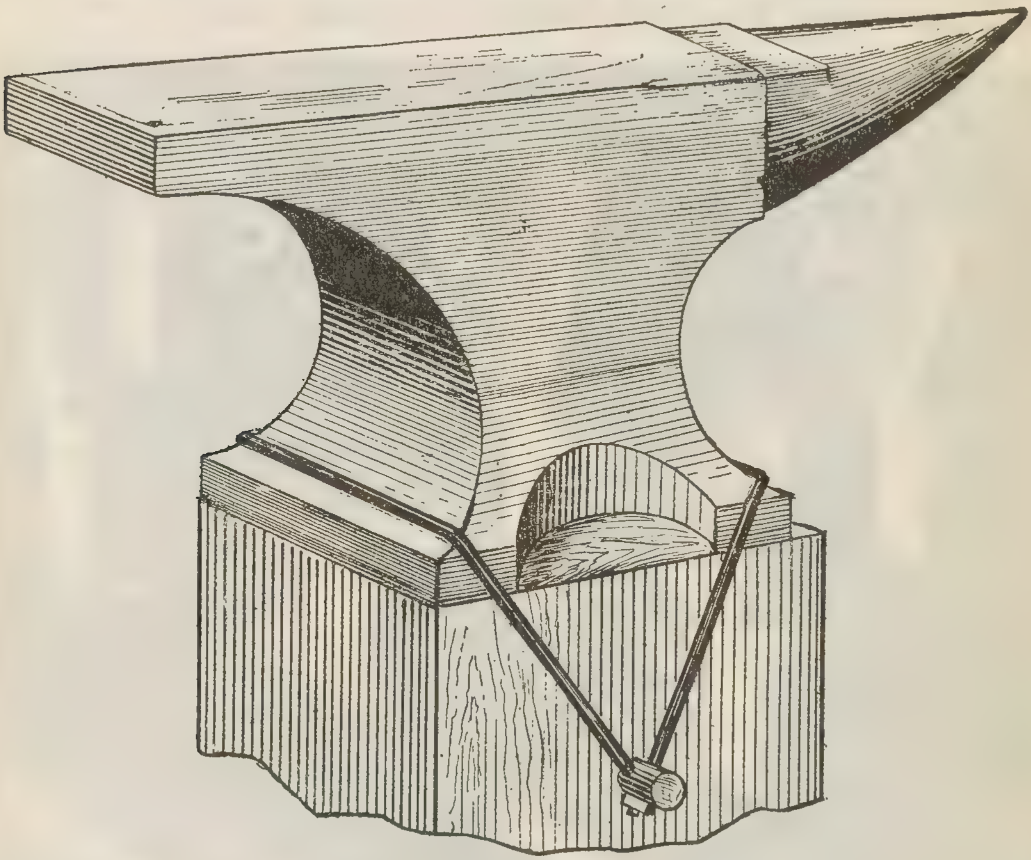


FIG. 9,896.—Method of anchoring an anvil to a wooden base.

The *punch* or *slug hole* is used in punching to provide a space through which the slugs may pass.

The cutting block, which is not hardened, is used for placing stock to be cut with a chisel.

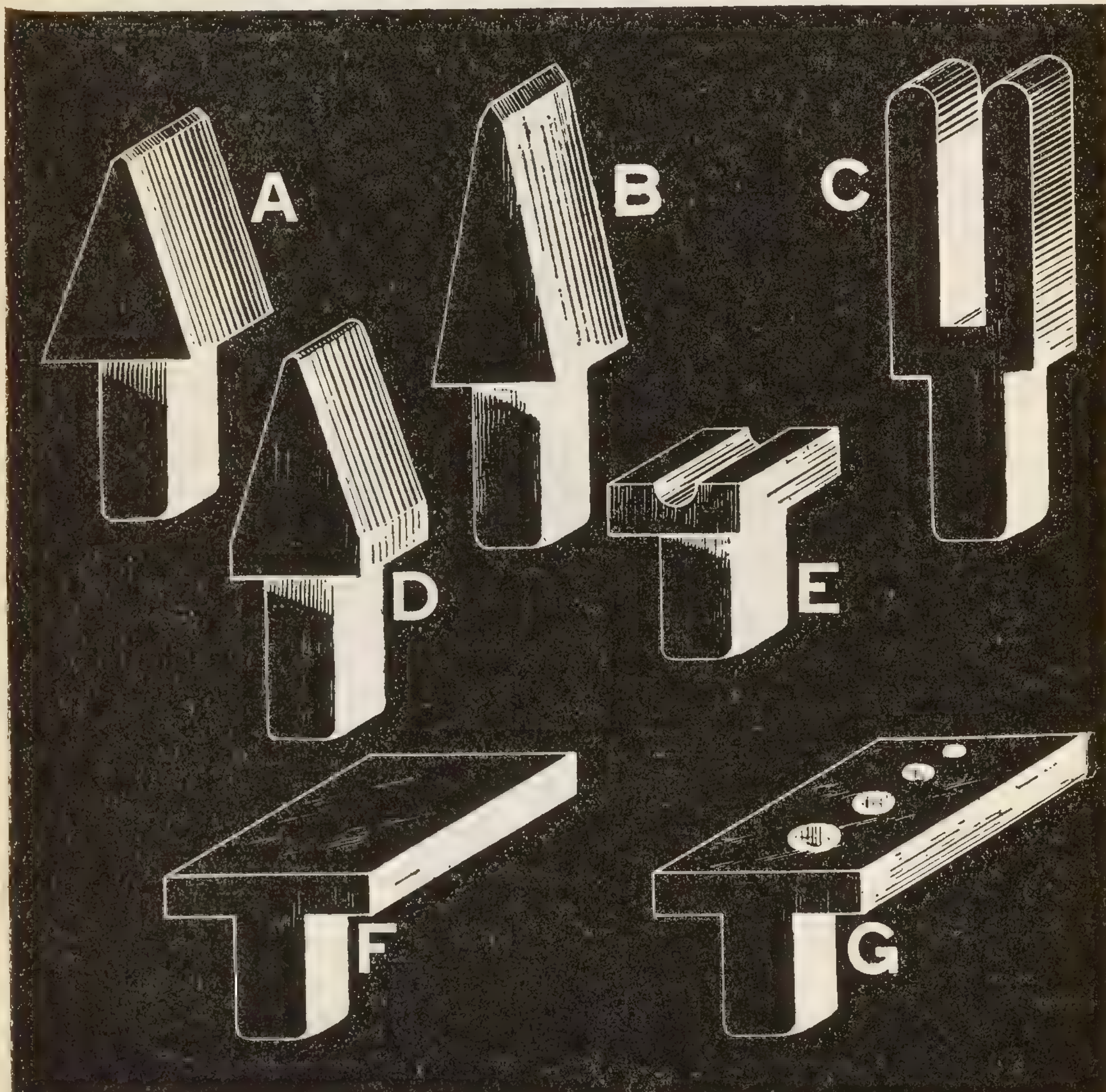
The *horn* or *beak* serves as a mould for bending curved portions of the work. The horn should be well dressed, smooth and drawn to a small round point.

The *heel* presents a flat working surface, and its corners and edges should be comparatively sharp.

The *body* should be amply large to quickly absorb the heaviest blows.

The *feet* (four in number) serve to increase the base upon which the anvil rests as well as to afford the means for clamping it down into position.

The anvil should be placed upon the end of the heavy block of wood sunk into the ground to a depth of at least two feet, so that it may rest upon a firm but elastic foundation. As the anvil is subjected to constant vibrations, by nature of the work, it is necessary that it should be firmly fastened to the block. In doing this, avoid spiking, as the spikes will soon work loose and the block be spoiled. A very convenient and reliable method of holding the anvil is shown in fig. 9,896. There are two iron



FIGS. 9,897 to 9,903.—Anvil tools. **A,** cold cut bottom hardy; **B,** hot cut bottom hardy; **C,** bending fork; **D,** bottom fuller; **E,** bottom swage; **F,** cutting block; **G,** punching block.

rods about $\frac{3}{8}$ in. in diameter passing over the feet of the anvil and running through a 1 in. round or square bar extending through the block. Nuts on these rods make it possible to draw them very tight and thus hold the anvil firmly.

Anvil Tools.—Under this heading is included all the tools provided with a tang, so that they may be held in the hardy hole of the anvil as distinguished from the tools erroneously called "anvil tools," held in the smith's hand and used in combination with the anvil tools; they are properly called *hand forming tools*. The anvil tools ordinarily used for general work, and which should always be included in any blacksmith's shop equipment are

1. Bottom hardies
   a. Cold cut
   b. Hot cut
2. Bending fork
3. Bottom fuller
4. Bottom swage
5. Cutting block
6. Punching block.

These are illustrated in figs. 9,897 to 9,903.

Hardies.—These are bottom cutting chisels used to cut off lengths from bars, or crop ends from forgings. They are called *cold* or *hot* according as they are shaped and tempered for cutting cold or hot iron, being shown in figs. A and B respectively.

Bending Fork.—This tool is made with square, flat or round fingers, as shown in fig. C, and is used extensively in a variety of bending operations.

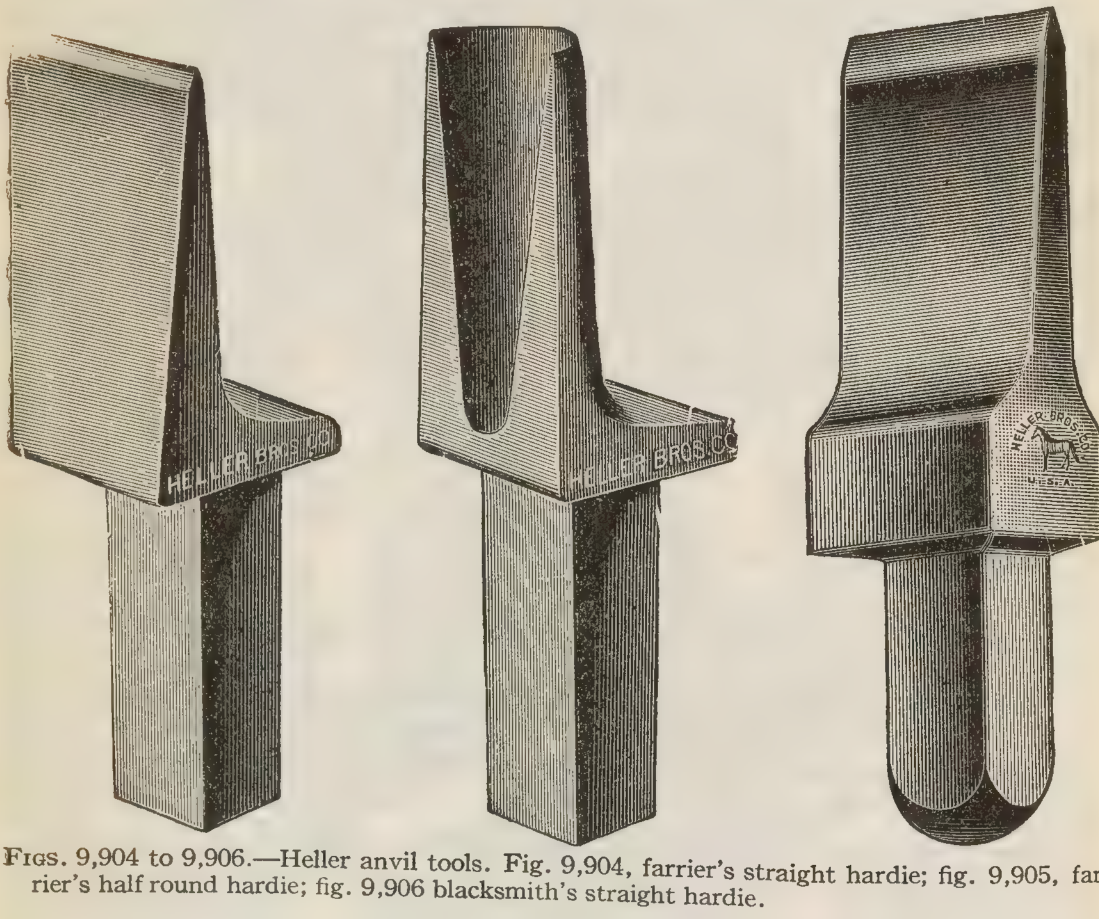
Bottom Fuller. This tool as shown in fig. D is simply an inverted wedge with a blunt nose or working edge. It is used for spreading or notching the work.

Bottom Swage.—The most common form of swage, as shown in fig. E, has a concave face and is accordingly used to smooth off a round bar. It is also used for drawing metal down to a required diameter.

Cutting Block.—A flat plate of mild steel as shown in fig. **F** to be used for cutting operations, which because of the shape of the work, cannot be conveniently performed on the cutting face of the anvil.

Punching Block.—A block similar to the cutting block, but provided be with a series of holes of various sizes as shown in fig. **G**. The holes provide a space through which slugs punched from the work may pass.

It should be understood that in addition to the standard anvil tools just described, there are numerous special tools occasionally used.

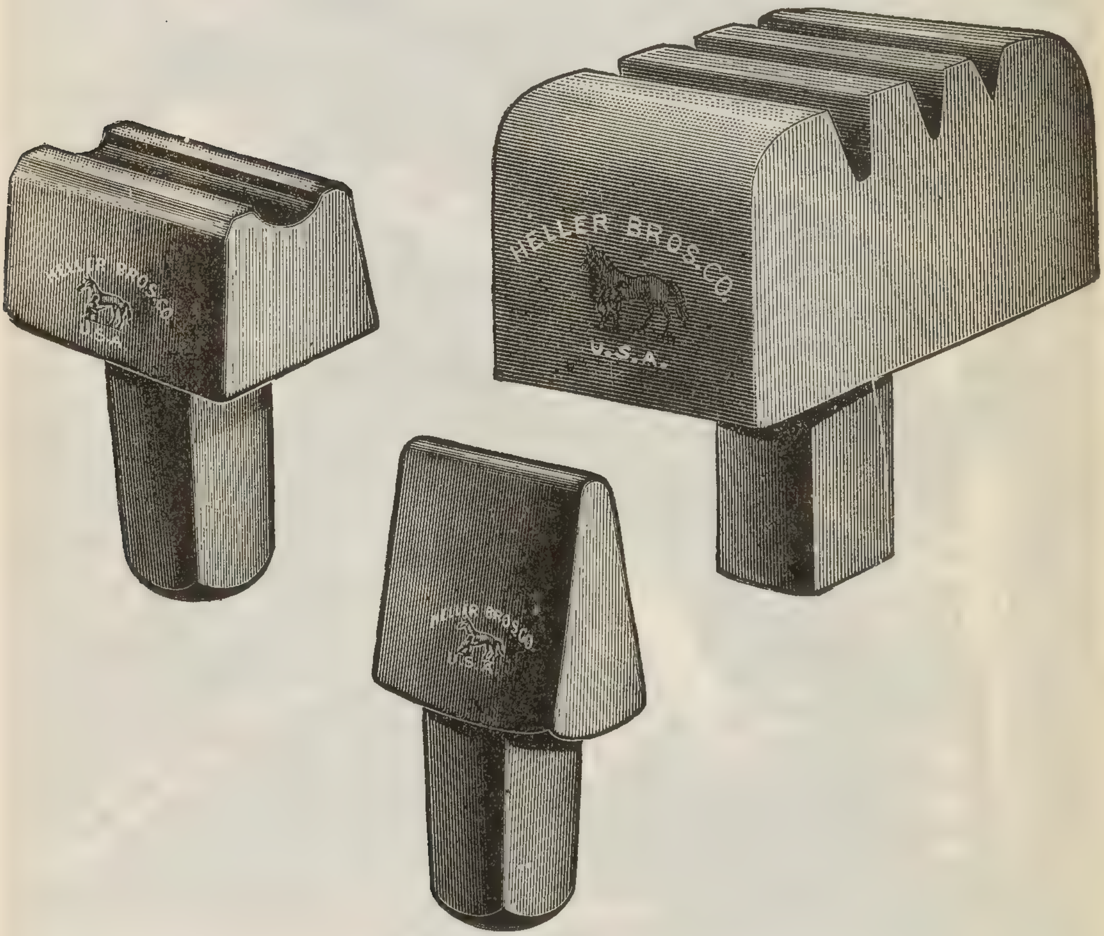


FIGS. 9,904 to 9,906.—Heller anvil tools. Fig. 9,904, farrier's straight hardie; fig. 9,905, farrier's half round hardie; fig. 9,906 blacksmith's straight hardie.

Hand Forming Tools.—These are virtually counterparts of the anvil tools. and are used in combination with the anvil tools. The author calls them hand forming tools because they are provided with a handle so that they may be held by the

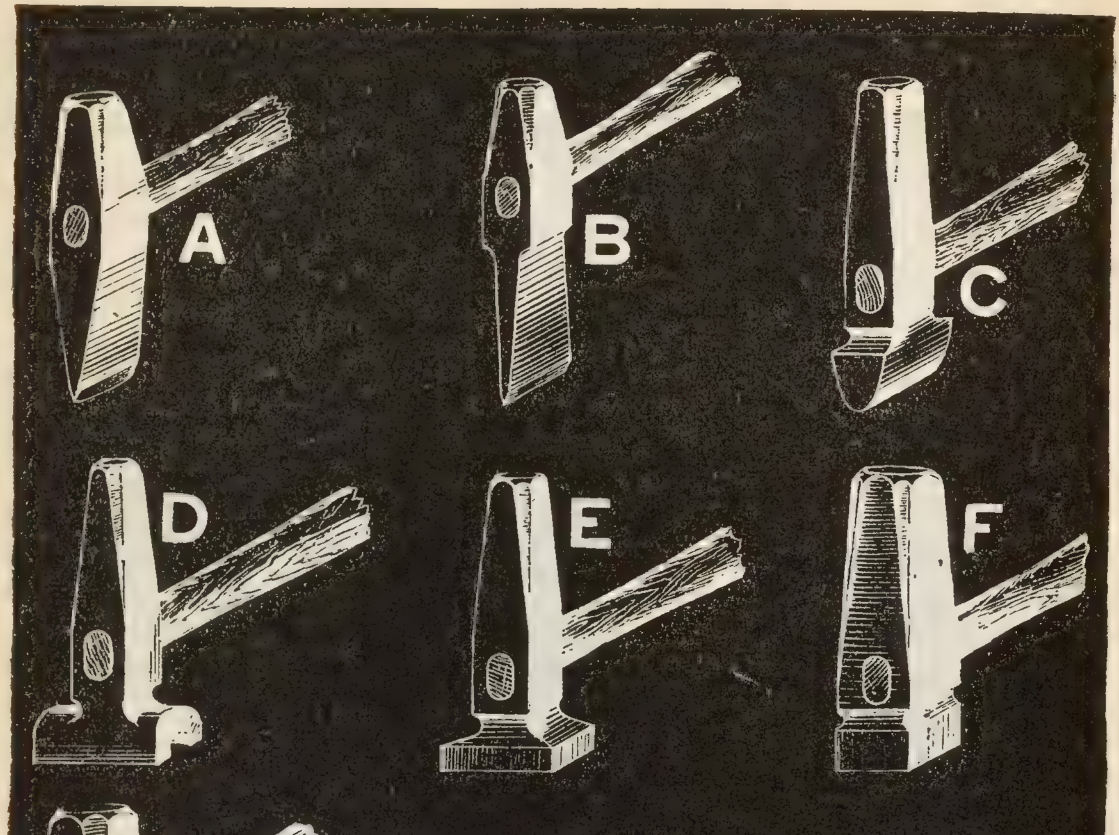
smith's hand in *forming* or shaping the work, the corresponding anvil tool used at the same time being held by the anvil by inserting the tang into the hardy hole of the anvil. The hand forming tools ordinarily used are

1. Top hardies
   a. Cold cut
   b. Hot cut



Figs. 9,907 to 9,909.—Heller anvil tools. Fig. 9,907, bottom swage; fig. 9,908, bottom fuller; fig. 9,909, small toe calk welding die.

2. Top fuller
3. Top swage



FIGS. 9,910 to 9,922.—Hand forming tools. **A**, cold cut top hardy; **B**, hot cut top hardy; **C**, top fuller; **D**, top swage; **E**, flatters; **F**, set hammer; **G**, handle punch, various shapes; **H**, cupping tool; **I**, heading tool; **J**, heading and bucking tools.

4. Flatters
    a. Plain
    b. Offset
5. Punches
6. Cutting tool
7. Bucking bar
8. Heading tool
9. Sheering tool.

The smith, in forming his metals, holds these tools in position by the handle, while the helper strikes the head of the placed tool with a sledge. Figs. **A, B,** etc., below refer to 9,910 to 9,922.

Cold Cut Top Hardy.—A stout bladed tool as shown in fig. **A,** used to cut cold metals.

Hot Cut Top Hardy.—A thin bladed tool as shown in fig. **B,** This tool should never be used to cut cold metal.

Top Fuller.—A tool having a rounded nose, as shown in fig. **C,** used for spreading and notching metals.

Top Swage.—A tool having a grooved face as shown in fig. **D,** used to "swage" or form metals to the shape of the groove, or for drawing metal down to a required diameter.

Flatters.—The set hammer form of flatter as shown in fig. **F,** may be properly called a hand forming tool when used to smooth off and finish small flat surfaces. Its principal use is for striking blows in a definite spot or inaccessible place. A regular flatter is a flat faced tool as shown in fig. **E,** used to smooth and finish the surface of forgings. To get the best smooth finish do not have the temperature of the forging too high, dip the face of the flatter in water, have water on the face of the anvil, and do not strike the flatter too heavily.

Punches.—These are used for making large holes in hot metal. The general appearance of a punch is shown in fig. **G.** The working end is shaped according to the kind of hole desired, as round, square, oblong, etc. The size depends upon the hole to be punched. They are invariably used for making holes through hot metal. The ordinary method is to punch part way through from one side; then turn the piece and drive through from the

opposite direction. This avoids tearing the metal on the surface, and leaves a smooth hole at each end.

Cupping Tool.—A tool with a rounded cavity as shown in fig. **H**; used for finishing the heads of rivets.

Bucking Bar.—This may be called an *inertia* tool and to possess that property in sufficiently marked degree it is made heavy. The bar, as shown in fig. **J**, has a suitable cavity in its working face and is used to "buck" or back up a rivet while it is being headed.

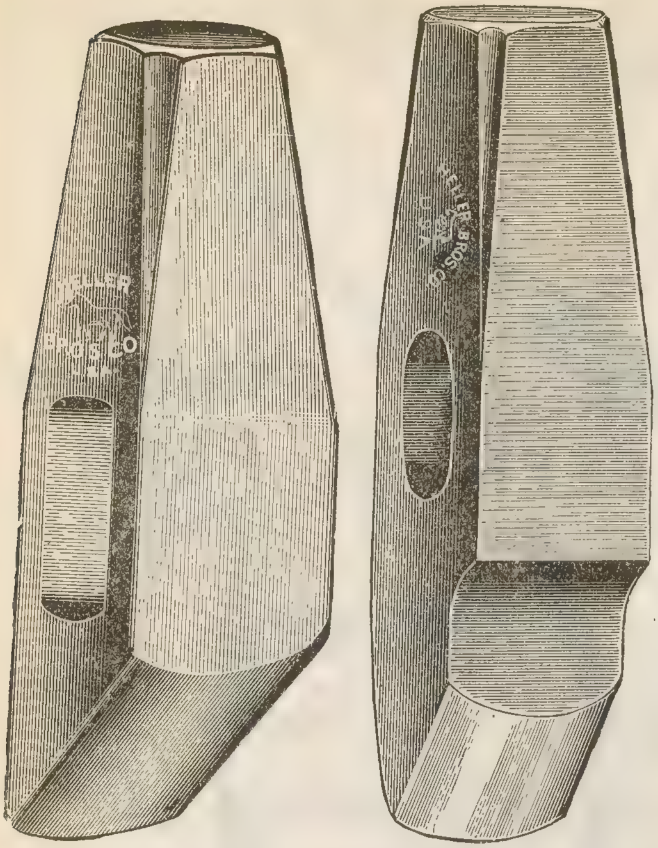
Heading Tool.—A tool used for making up bolt heads as shown in fig. **I**. It has a hole about 1/32 in. larger than the diameter of the stock that is being used, the face end of the hole being beveled.

Shearing Tool.—The cutting end of this tool is ground to the proper angle to adapt it to the work for which it is intended.

Swage Block.—In connection with the use of the swage which is used for drawing metal down to a required diameter, a swage block is very convenient. It takes the place of both the anvil and the bottom swage and is illustrated in fig. 9,927. It is usually made of cast iron of an approximately square shape, with a number of grooves of different dimensions cut on the face. These grooves are used according to the diameter and

FIGS. 9,923 and 9,924.—Heller hand forming tools. Fig. 9,923, cold chisel; fig. 9,924, hot chisel.

shape of the piece being worked. It is called a swage block. The grooves at H, are semi-elliptical, which should also be the shape of the curve of the top swage. The angular grooves are right angled and are adapted to receive different sizes of square iron. The holes through the casting are available for punching, drifting, etc.



FIGS. 9,925 and 9,926.—Heller hand forming tools. Fig. 9,925, creasing fuller; fig. 9,926. Scotch pattern creasing fuller.

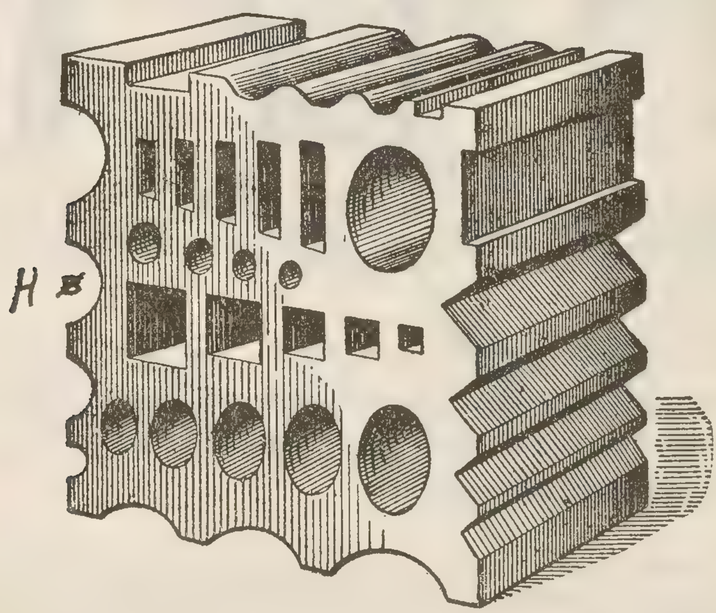
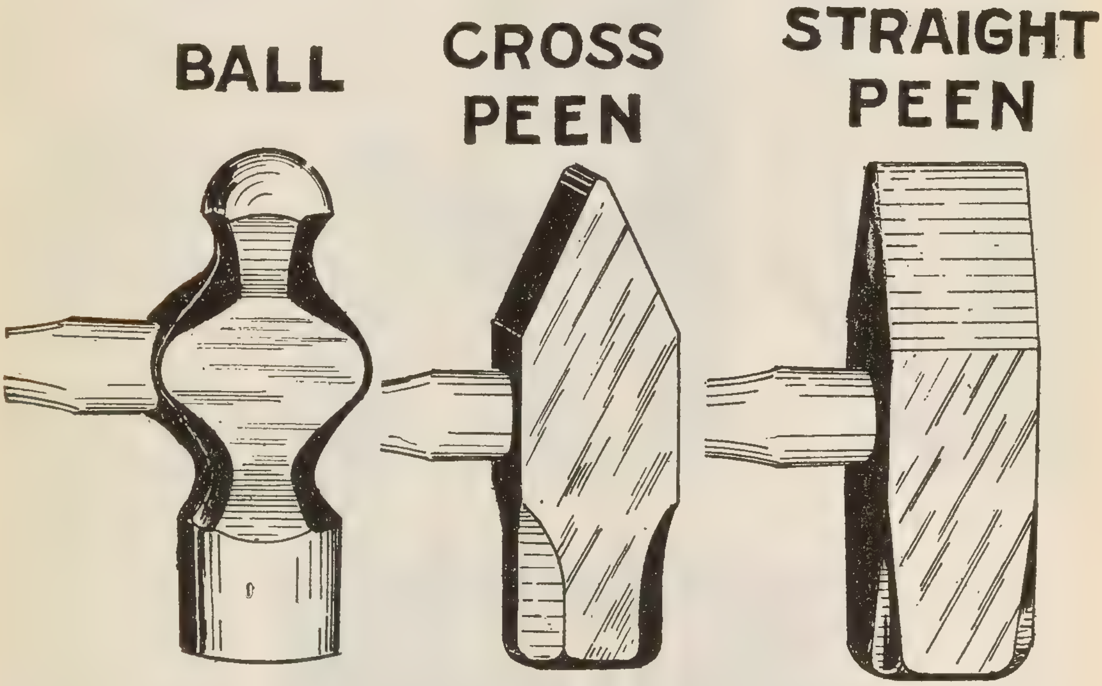


FIG. 9,927.—Swage block.

Hammers.—Ordinarily five kinds of hammers are used in a blacksmith's shop and they are known as:

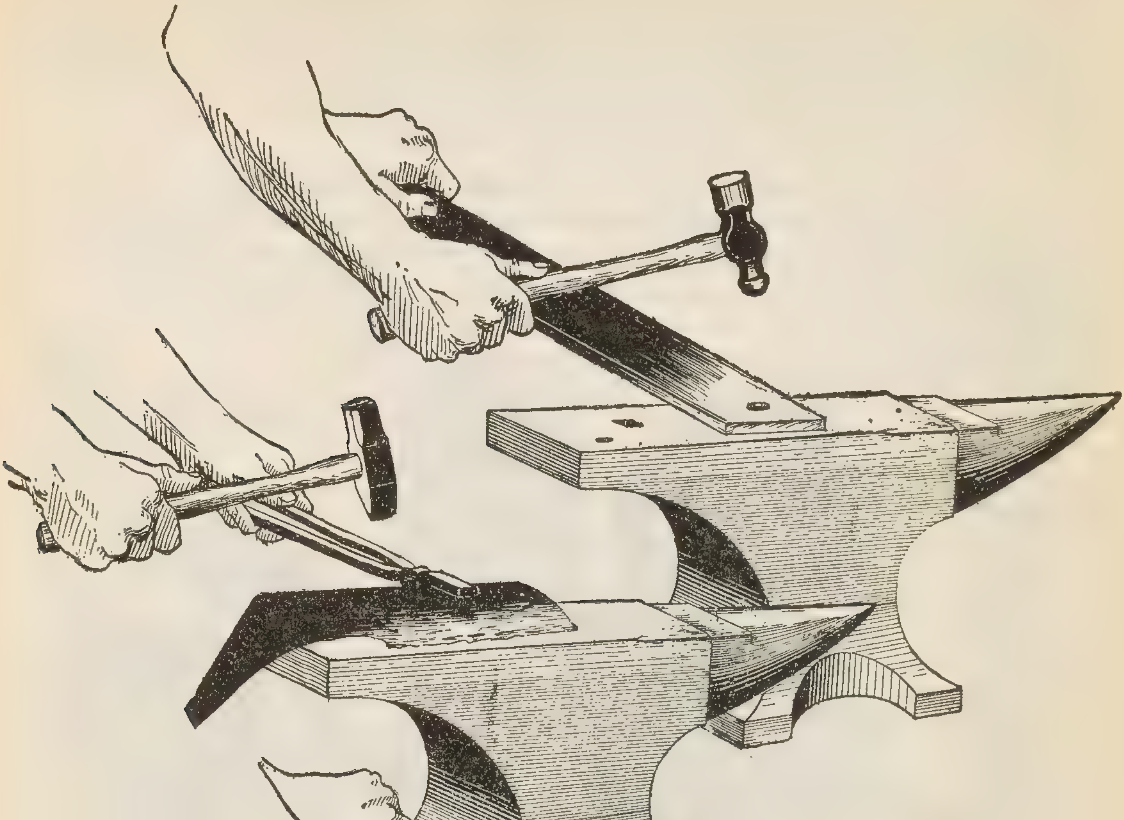
1. Ball peen
2. Cross peen
3. Straight peen
4. Riveting
5. Sledge.



FIGS. 9,928 to 9,930.—Various blacksmith's peen hammers. Fig. 9,928 ball; fig. 9,929, cross; fig. 9,930 straight. The straight peen hammer varies in weight from 1½ to 3½ lbs. The ball peen hammer varies in weight from ½ to 5 lbs. for general use the 3 lb. size being suitable.

By definition the word *peen* (also spelled *pein*) means the *end of a hammer head opposite the face when adapted for striking; usually shaped for indenting, as when pointed, conical, hemispherical, or wedge shaped.*

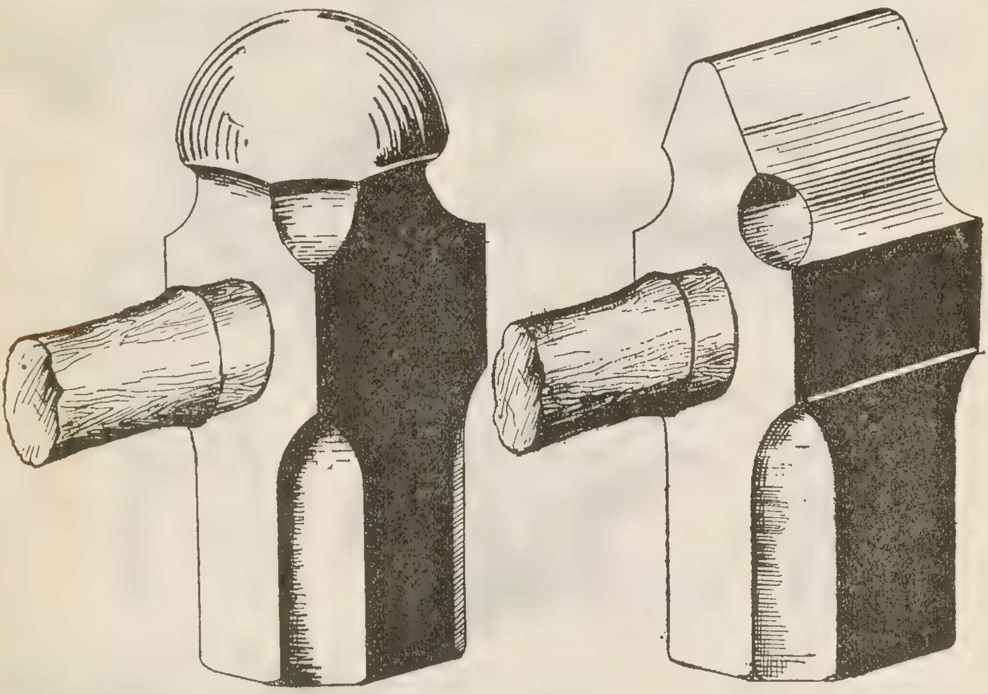
The ball, cross and straight peen hammers are shown in figs. 9,928 to 9,930, and some of the uses for which the hammers are suitable, in figs. 9,931 to 9,933.



FIGS. 9,931 to 9,933.—Some operations performed with peen hammers. Fig. 9,931 making countersink around a hole; fig. 9,932, drawing out plow share; fig. 9,933, drawing out the end of a piece of metal as in making tongs.

All hammers used directly upon hot iron or steel should have the centers of their faces slightly crowning or convex, and the edges well rounded off to prevent their leaving sharp and unsightly marks upon the work, which is very apt to be the case when a hammer with a perfectly level face and sharp edges is used even by experienced workmen.,

Sledge hammers are used by the blacksmith's assistant or *helper*, for making forgings heavier than could be successfully made by hand hammering alone. The sledge hammer is used both directly upon the hot metal in roughly blocking it to shape, and in finishing it by means of other tools which are placed upon the work and struck with the sledge. The most common pattern of the sledge is shown in fig. 9,934.



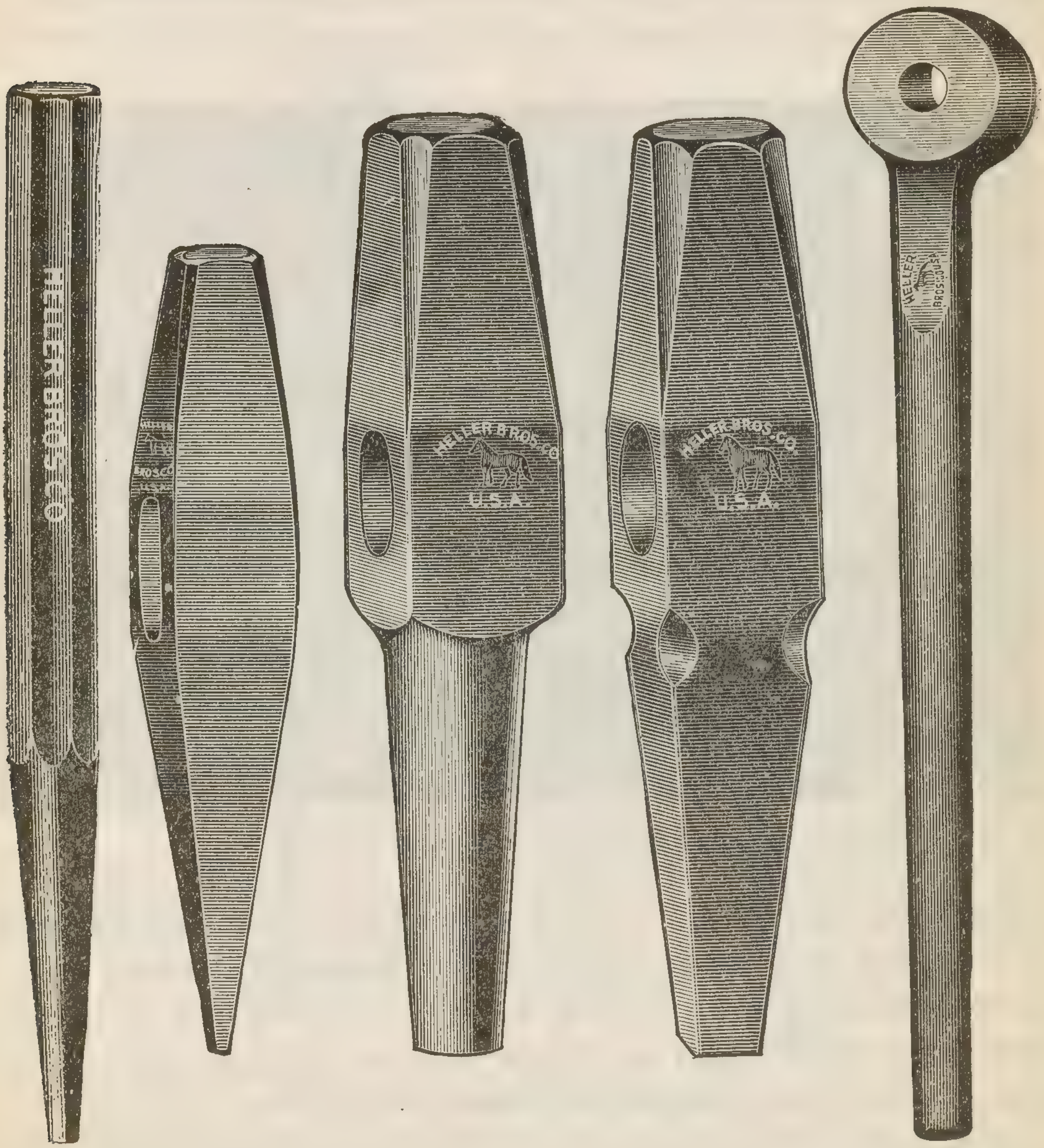
FIGS. 9,934 and 9,935.—Sledge hammers. Fig. 9,934, ball peen pattern; fig. 9,935, straight peen pattern.

The corners between the face and the eye are worked into octagonal shape, and the peen which is circular on the top, stands straight with the handle. The weight of sledge hammers varies according to the size and weight of the work for which they are used; some hammers only weigh 8 lbs, while others weigh 20 lbs. or over.

Smaller hammers of the same pattern, weighing less than 8 lbs. are called *quarter hammers*, and those used for the very lightest work, generally made with a ball peen like a hand hammer, as shown in fig. 9,935, are called *backing hammers*.

Forge.—This consists of an open fire place or hearth arranged for forced draft. The smith heats his metal to the working temperature in the forge. The principal parts of a forge are:

1. Fire pot
2. Hearth



Figs. 9,936 to 9,940.—Heller hand forming tools. Fig. 9,936, hand punch; fig. 9,937, fore punch; fig 9,938, round punch; fig. 9,939, square punch; fig. 9,940, heading tool, round or square hole.

3. Tuyere
4. Blower
5. Hood.

These are shown in fig. 9,941, from which it is seen that the fire pot consists of an inverted conical shaped vessel. The fire is built in the fire pot. At the lower end of the fire pot is the tuyere which is simply a pipe, one end of which projects

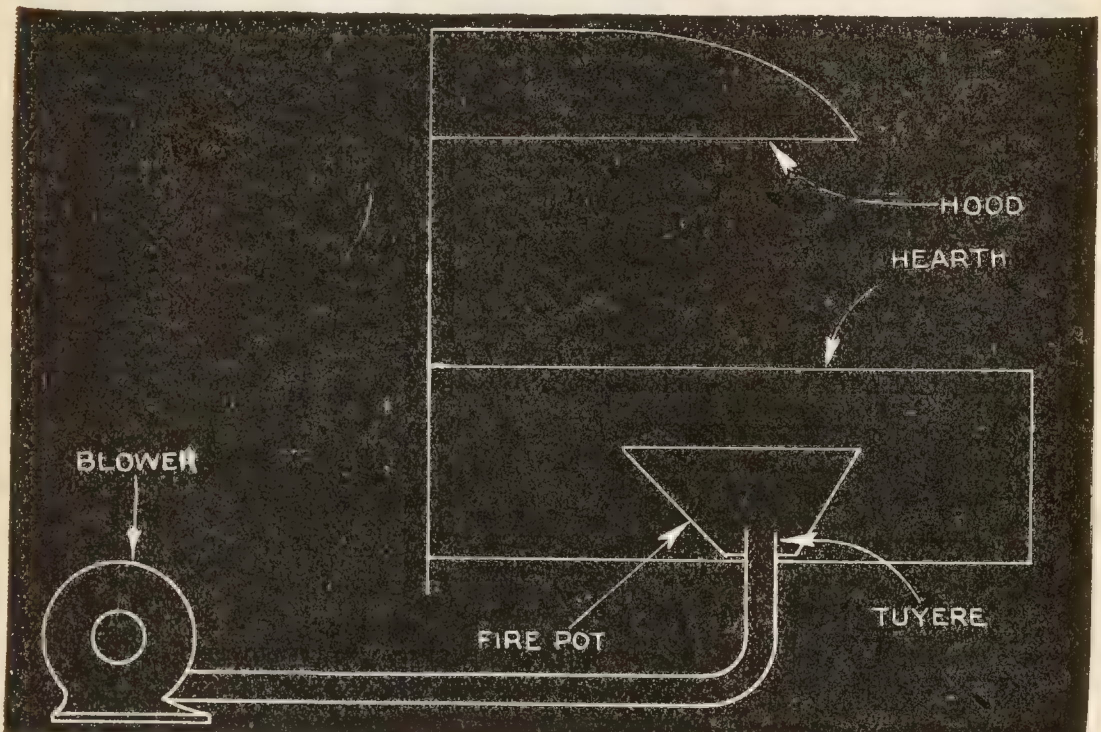


FIG. 9,941.—Elementary blacksmith's forge showing essential parts.

into the bottom of the fire pot and through which a blast of air obtained by a blower (or bellows) is used for forced draft. Surrounding the fire pot is a large box like casing or hearth filled with cinders and on which coal is tamped around the fire on which the metal to be heated is rested.

The small circular type forge, owing to its portability, can be carried into the field for such purposes as tool dressing and the like.

The best type of portable forge may be taken apart into three pieces by the disconnection of a few wing nuts; fan, pan and legs, packing separately for transportation. Wherever more than rivet heating or chisel dressing is intended, it is advisable to use a large square pan forge, of a more substantial type.

As bellows are undesirable, a forge 28 ×40 ins. may be recommended with a 14 in. fan; the latter will be driven by means of a lever through a sort of sun and planet motion, or by the intervention of a chain like the gear chain

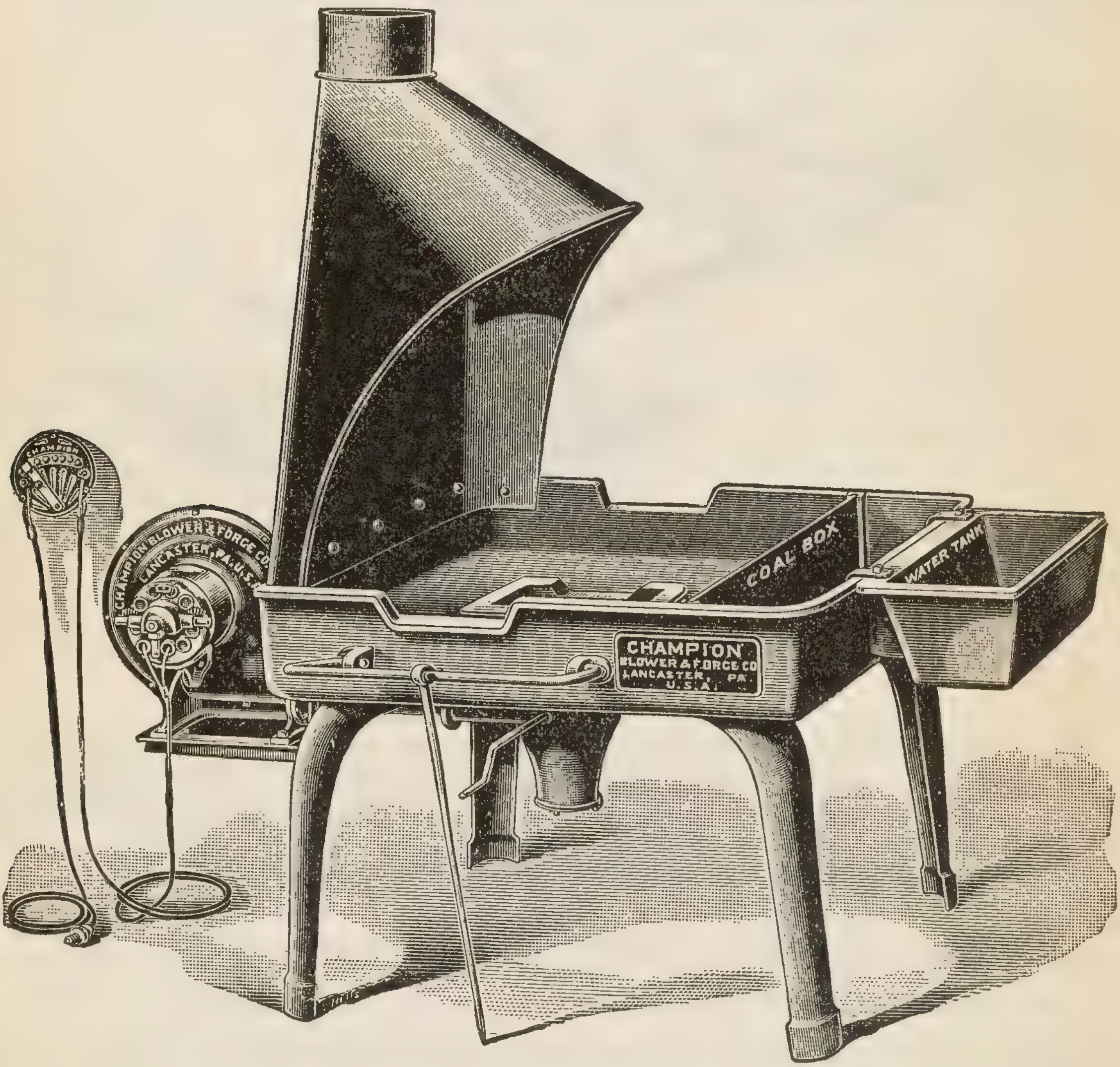
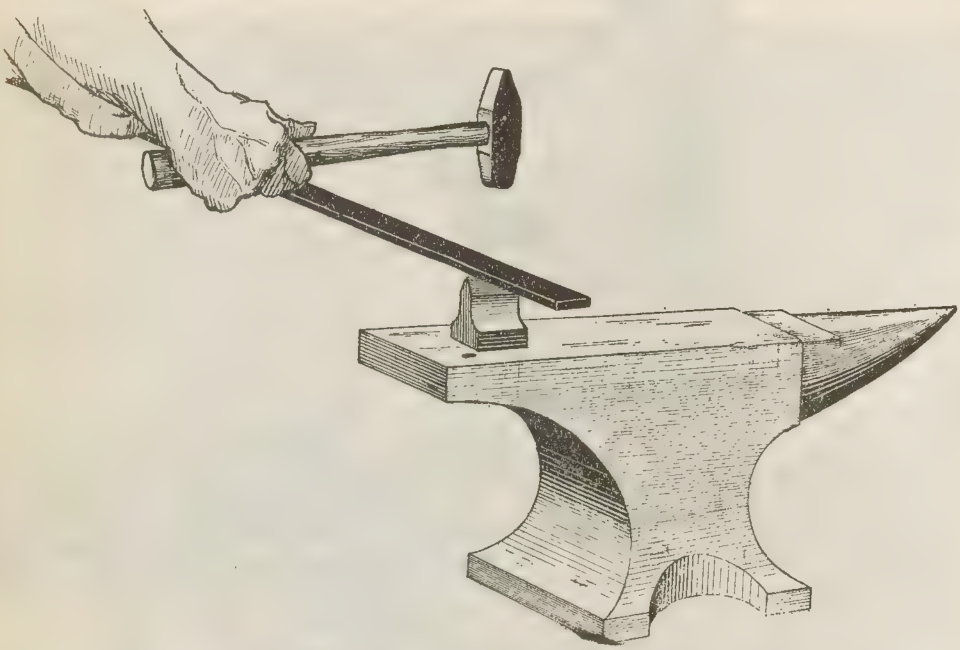


FIG. 9,942 and 9,943.—Champion cast iron hearth blacksmith's forge. ***In construction,*** the hearth is 32 × 45 ins and is supplied with a sloped bottom coal box which is entirely out of the way, as it is beneath the level of the bottom of the hearth, thus keeping the coal in any degree of dampness that the operator desires. The fan blower has spiral gear transmission, each turn of the crank producing 46 revolutions of the fan. Crank turns either way.

of a bicycle, from a large sprocket wheel. In either case the final multiplying power is transmitted to the fan pulley by a belt; as a plain flat leather or textile one.

It is claimed, with a forge of these dimensions, that a welding heat can be obtained on a 3 in. bar in 5 minutes, and on 4 in. iron in 10 minutes. With the addition of a bosh or water tank this forge will weigh about 300 lbs.

Forge Operation.—The fuel used on the forge is bituminous coal. It should contain as little sulphur and earthly matter



FIGS. 9,944.—***Cutting 1.*** With bottom hardy. Place hardy in hardy hole. Grasp piece to be cut and strike a series of blows with the hammer turning piece (if of round section) while hammering; if piece be flat, hammer first on one side and then on the other. ***In turning*** the piece over, be careful that the edge of the hardy is placed directly under the indentation just made on the other side. The piece to be cut should be cold or heated, according to whether the cold cut or hot cut hardy be used. The illustration shows cutting with the cold cut hardy.

as possible. The best quality coal is called smithing coal, although charcoal or coke may be used. In building a fire, place a block or brick over the tuyere opening and back the coal in the fire pot, then remove the block or brick and insert shavings in the opening. When the shavings are well ignited place some coke on them and accelerate the fire with the

blower. Add a quantity of smithing coal well damped with water and partially burn out the gases.

The depth of the fire should always be liberal, because with a shallow fire the blast will blow through the fire, and the excess air will rapidly oxidize the metal being heated. The fire should be limited to as small a space as is necessary to heat

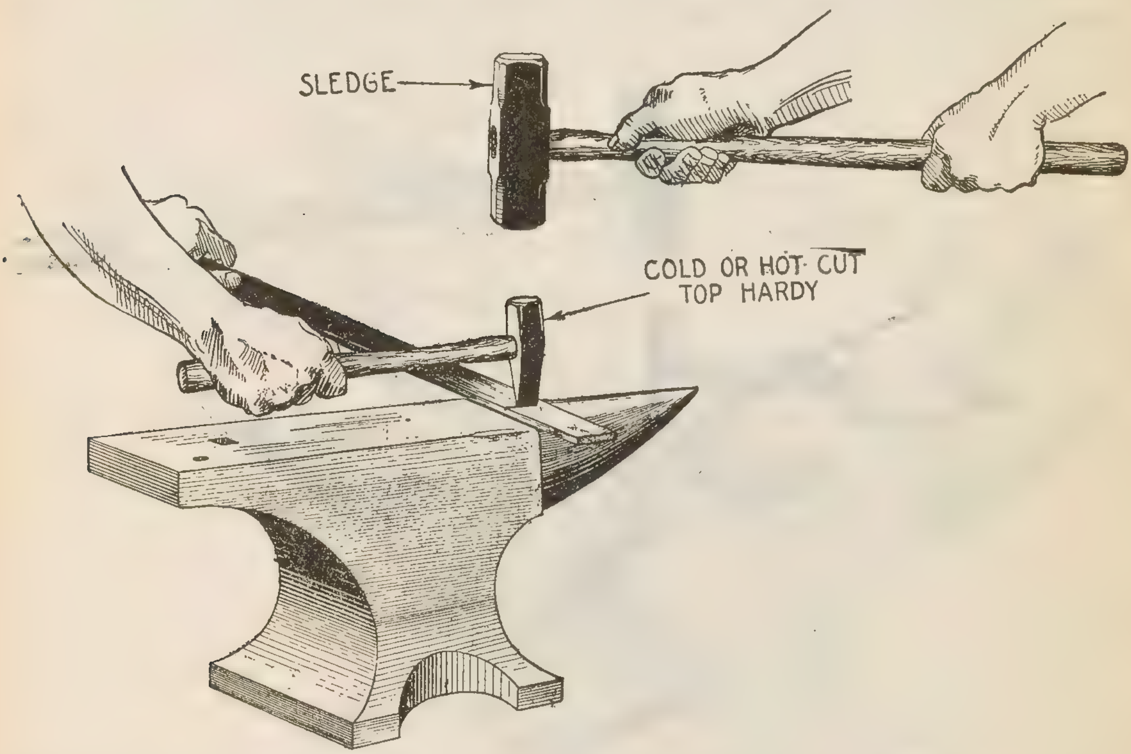


FIG. 9,945.—*Cutting 2.* With cold or hot cut top hardy (light cutting). Place the piece to be cut on the cutting face of the anvil. Hold piece with one hand and top hardy with the other. Place hardy squarely across piece to be cut and nick or deeply cut by blows delivered by helper with sledges. This operation is performed on the cutting face rather than the hardened face because the former is soft and in case the last blow severs the piece being cut, it would not result in injury to the tool or anvil as would perhaps happen on the hardened face. A good smith is very careful about marring the hardened face, as good work cannot be done unless this face be in perfect condition.

the metal. It is regulated by quenching around its exterior portion. Only use the blast when heating the metal, and if it be desired to keep the fire for any length of time it should be well banked.

Fluxes.—A flux is a substance, such as borax, which promotes the fusing of metals; thus in soldering tin ware, rosin is used as a flux; the flux forms a skin on the surface of the heated metal and protects it from the attack of the oxygen in the atmosphere. The light blows given in the first stage of welding expel both flux and scale from the joint.

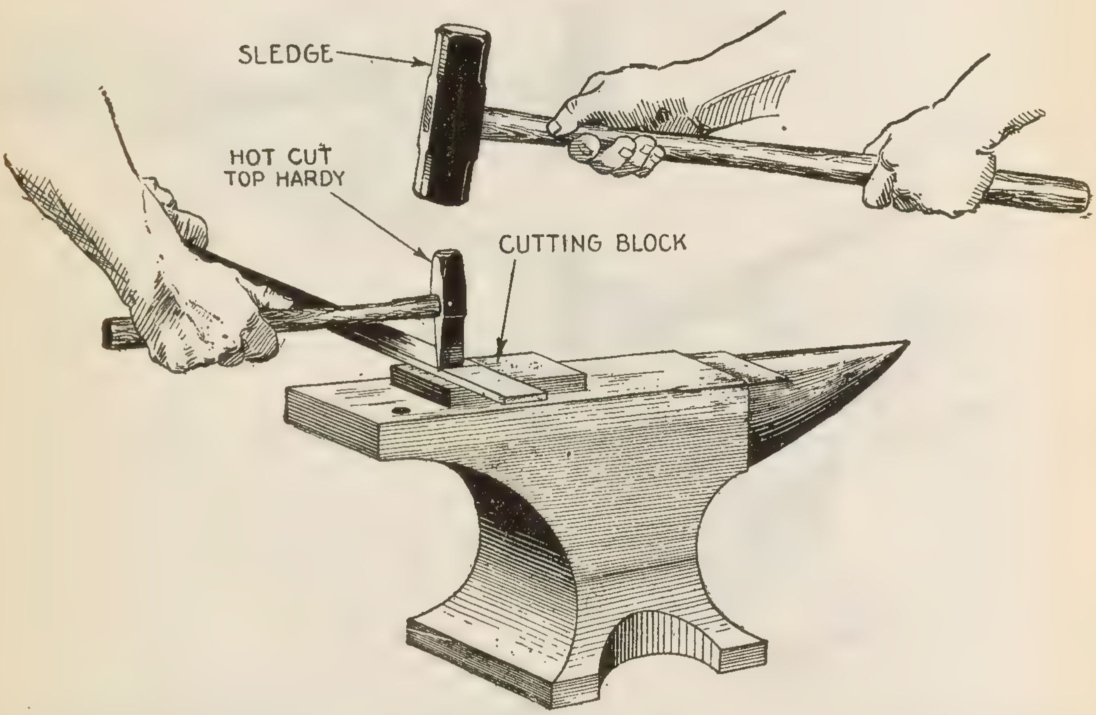


FIG. 9,946.—*Cutting 3.* Heavy cutting with hot (or cold cut) top hardy on cutting block. This is done in a similar manner as in fig. 9,945, except that the piece to be cut is placed on the cutting block which is held by placing its tang in the head hole.

In practical operation the smith often uses a little fine sand to sprinkle over the portions of the iron; ordinary borax is often applied for the same purpose, especially with mild steel.

A flux used for uniting steel with wrought iron consists of six parts of powdered limestone mixed with one of sulphur, the ends of the two portions

being dipped in the mixture four or five times while heating, before actually welding.

When uniting steel with steel, the following is recommended: borax, 4 oz. washing potash, 4 oz. and a small quantity of ground glass. All should be melted together and pulverized when cold.

Several authorities give the following formula for use with steel, and it will repay for the trouble incurred in its manufacture:

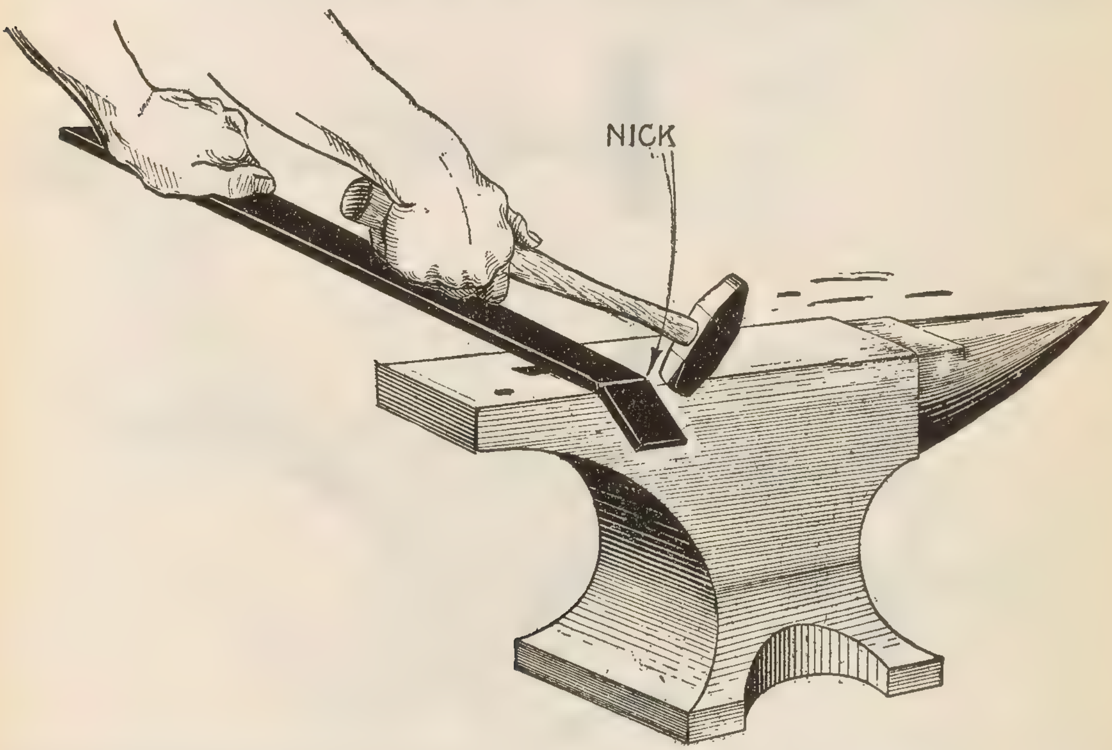


FIG. 9,947.—***Cutting 4.*** By nicking. The piece to be cut having been nicked on both sides as in figs. 9,944 and 9,945 it is placed with the nick over an edge of the anvil and broken apart by hammering. As the breaking operation is a bending action, the hammer blows should not be delivered too near the nick.

Take by weight: borax, 14 oz. sal-ammoniac, 2 oz.; prussiate of potash, 2 oz.; unrusted wrought iron filings, 1 oz. The whole is ground up with a pestle and mortar and then placed in a sheet iron pot or crucible (an old pail will do), together with sufficient water to make a thick paste. The vessel is boiled over a moderate wood fire, the contents being constantly stirred. A mass like pumice stone, streaked with grey and green results,

which is allowed to harden, is cooled, and once more pulverized, when it is ready for use.

Welding Steel.—In welding *cast or tool steel* the following points deserve careful study:

1. Do not use coal, as it may contain sulphur, but use coke, charcoal, or what is known as breeze, namely, washed and sorted cinders of partly burnt coal.

2. Keep the cast steel covered up while heating, and bring it to its heat as quickly as possible, with a view to prevent oxidization.

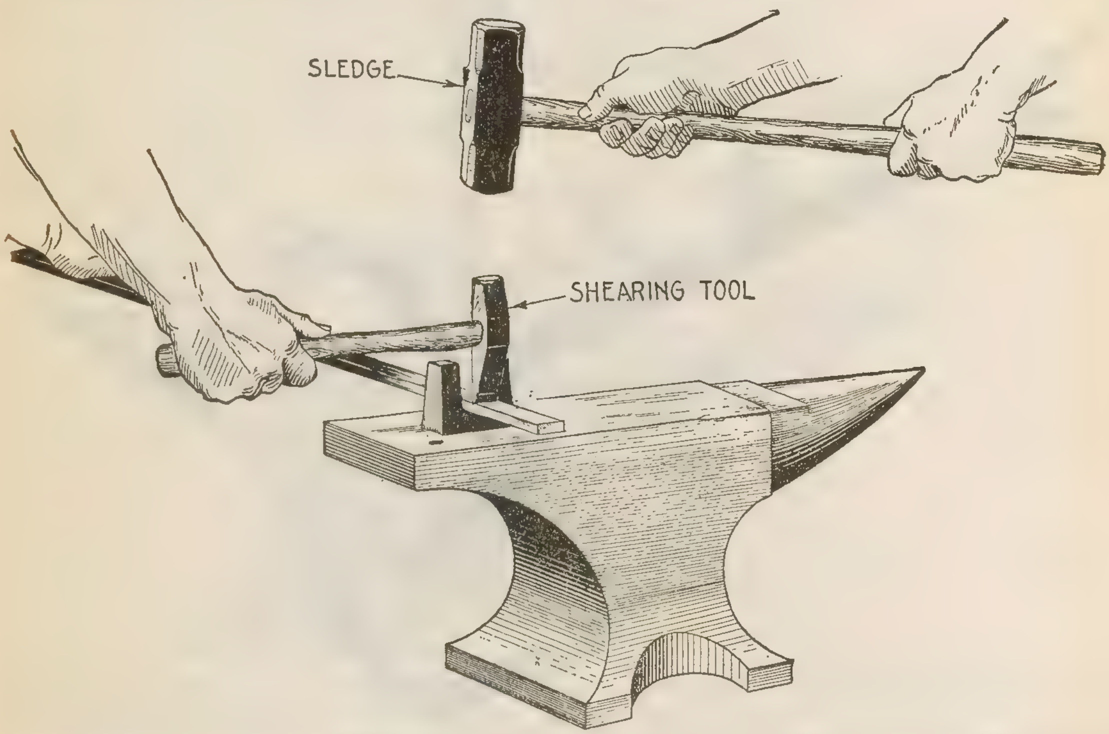


FIG. 9,948.—*Cutting 5.* With bending fork and sheering tool. Place bending fork in hardy hole and insert the piece to be cut between the two fingers of the fork. Hold sheering tool against side face of fork and sheer off piece by blows delivered by helper with a sledge.

3. As cast steel requires but a low welding heat, it must not be made too hot; in that case, it will either burn or break into pieces while being hammered.

4. Apply some flux (made as previously described) before putting the work into the fire, to protect the surface from the formation of scale or oxide, and add more at discretion, preferably as mentioned in a previous paragraph.

5. When welding steel and iron, the iron must be hotter than the steel.

6. Clean off both surfaces with a short besom or hand broom before putting the parts together, and sprinkle flux at the last moment.

7. Strike light blows and quick at first, and then increase to heavy blows at completion.

Temper of Steel.—This term, as used by steel makers, denotes the amount of carbon which is present in steel and its consequent hardness. The chief classifications are enunciated below:

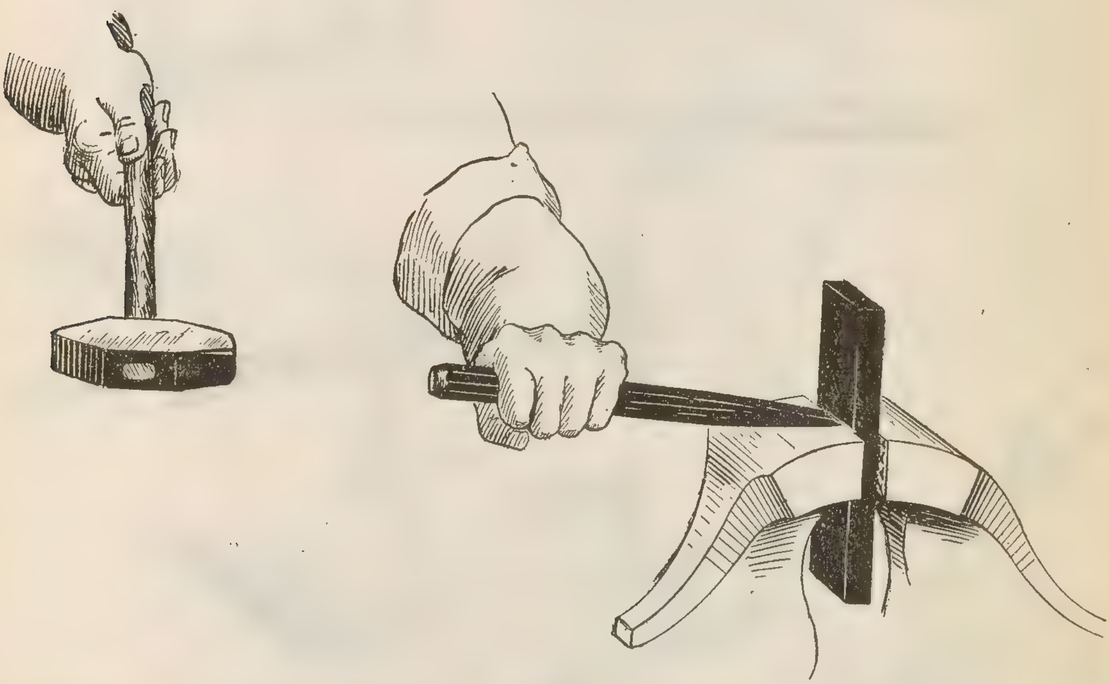
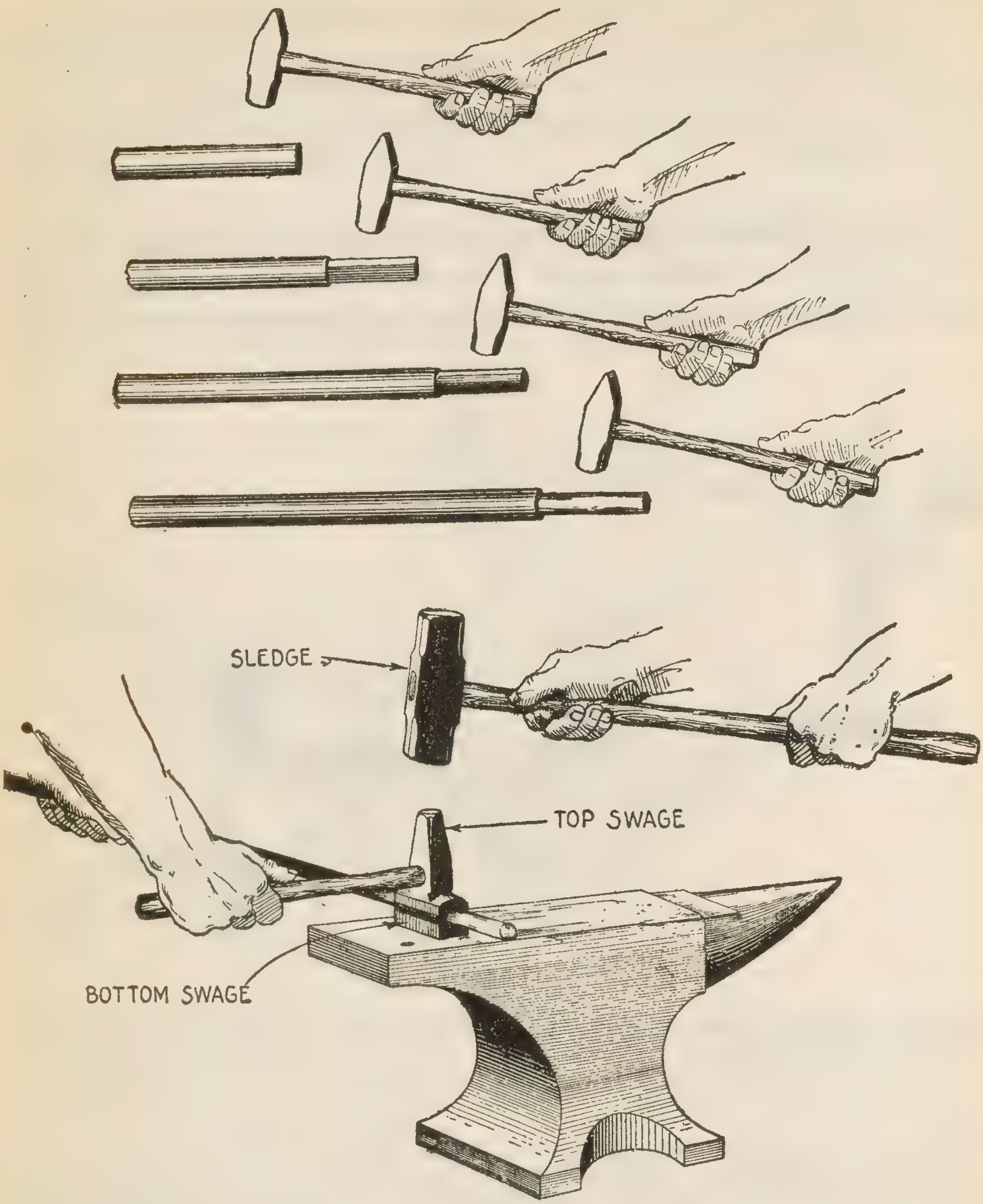
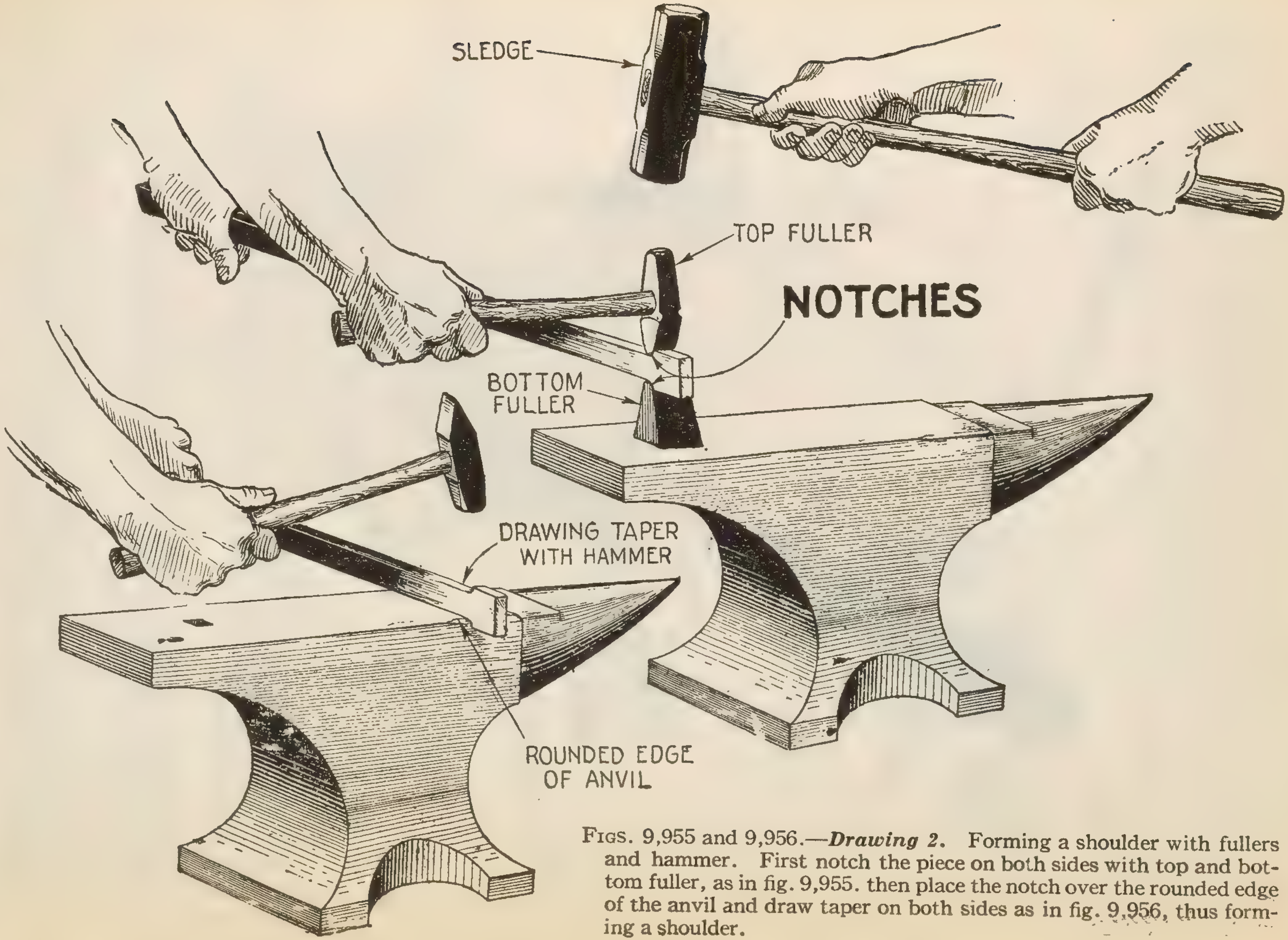


FIG. 9,949.—*Cutting 6.* With cold chisel. Place piece to be cut in vise and nick on both sides with cold chisel as shown.

Razor Temper.—This has 1½ per cent. of carbon, and is so easily overheated that its manipulation can only be entrusted to a person accustomed to work with it. When properly treated it will do twice the work of ordinary tool steel in turning chilled rolls, etc.



FIGS. 9,950 to 9,954.—***Drawing 1.*** Reduction of round stock with hammer. Owing to the difficulty of preventing the stock bending when the stock is kept round while hammering, it is advisable to first draw the piece to a square, as in fig. 9,951, then to octagonal shape as in fig. 9,952, after which it is hammered to rough round as in fig. 9,953, and finally their regularities removed by use of the top and bottom swages as in fig. 9,954.



FIGS. 9,955 and 9,956.—***Drawing 2.*** Forming a shoulder with fullers and hammer. First notch the piece on both sides with top and bottom fuller, as in fig. 9,955. then place the notch over the rounded edge of the anvil and draw taper on both sides as in fig. 9,956, thus forming a shoulder.

Varieties of Temper in Steel.—The following are some of the ordinary tempers which the blacksmith should understand:

In this case tempering relates to the degree of hardness obtained by plunging the steel when heated to a cherry red, into cold water.

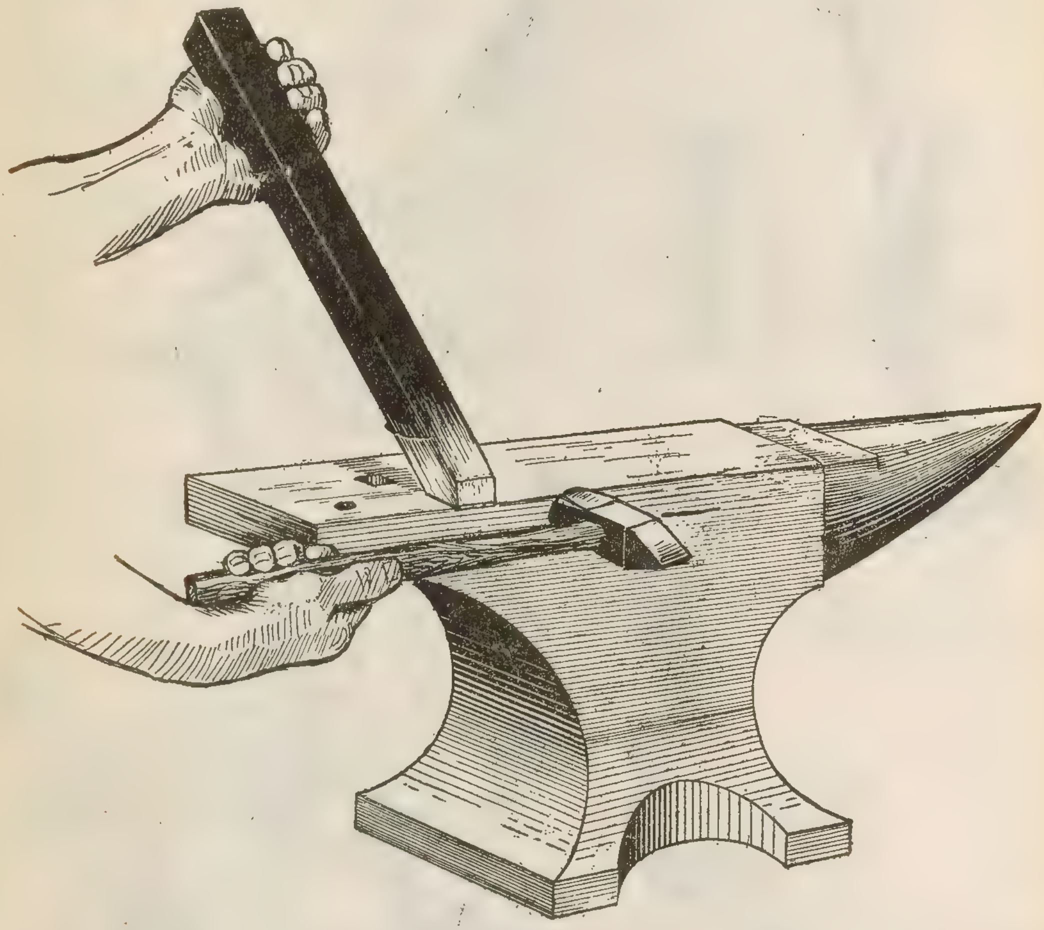


Fig. 9,957.—***Drawing 3.*** Forming a chamfer or short taper. Place a piece on anvil and hold at half the angle of the taper. In order to avoid striking the anvil the end of the piece to be champered should be held flush with the edge of the anvil. The drawing should take place at a high temperature.

Saw File Temper.—Contains $1\frac{3}{4}$ per cent. of carbon, and demands careful treatment. Although it will stand the fire better, it must not be heated above a cherry red.

Tool Temper.—This possesses $1\frac{1}{4}$ per cent. of carbon, and is the quality recommended for machine tools. This steel may be welded, but the operation demands skill and experience.

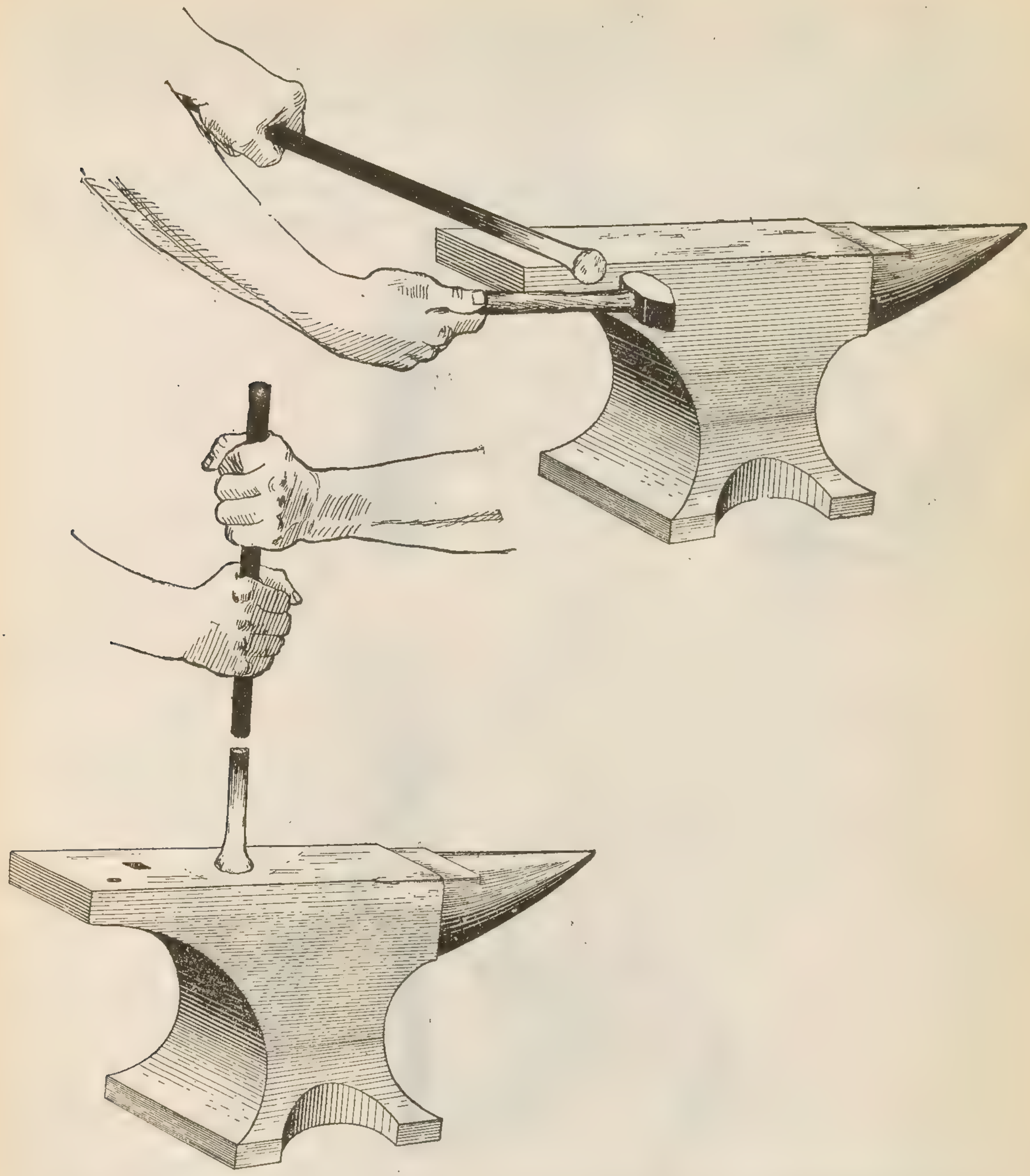


FIG. 9,958.—*Upsetting 1.* By ramming. A heavy piece owing to its inertia may be upset by simple ramming it against the face of the anvil.

FIG. 9,959.—*Upsetting 2.* By hammering (heavy bar). Lay bar across anvil and hammer end. The inertia of the bar together with the restraining force due to firmly holding bar on anvil will offer sufficient resistance as to cause the metal at the end of the bar to upset when hammered.

Spindle Temper.—With $1\frac{1}{8}$ per cent of carbon, this furnishes the best results for very large turning tools, milling cutters, taps and screwing tackle. Considerable care is required in welding it, the flux previously referred to (composed of borax, sal-ammoniac and yellow prussiate of potash) having been used with success.

Chisel Temper.—This useful temper has 1 per cent. of carbon, and possesses great toughness in its soft state. It hardens at a low heat and

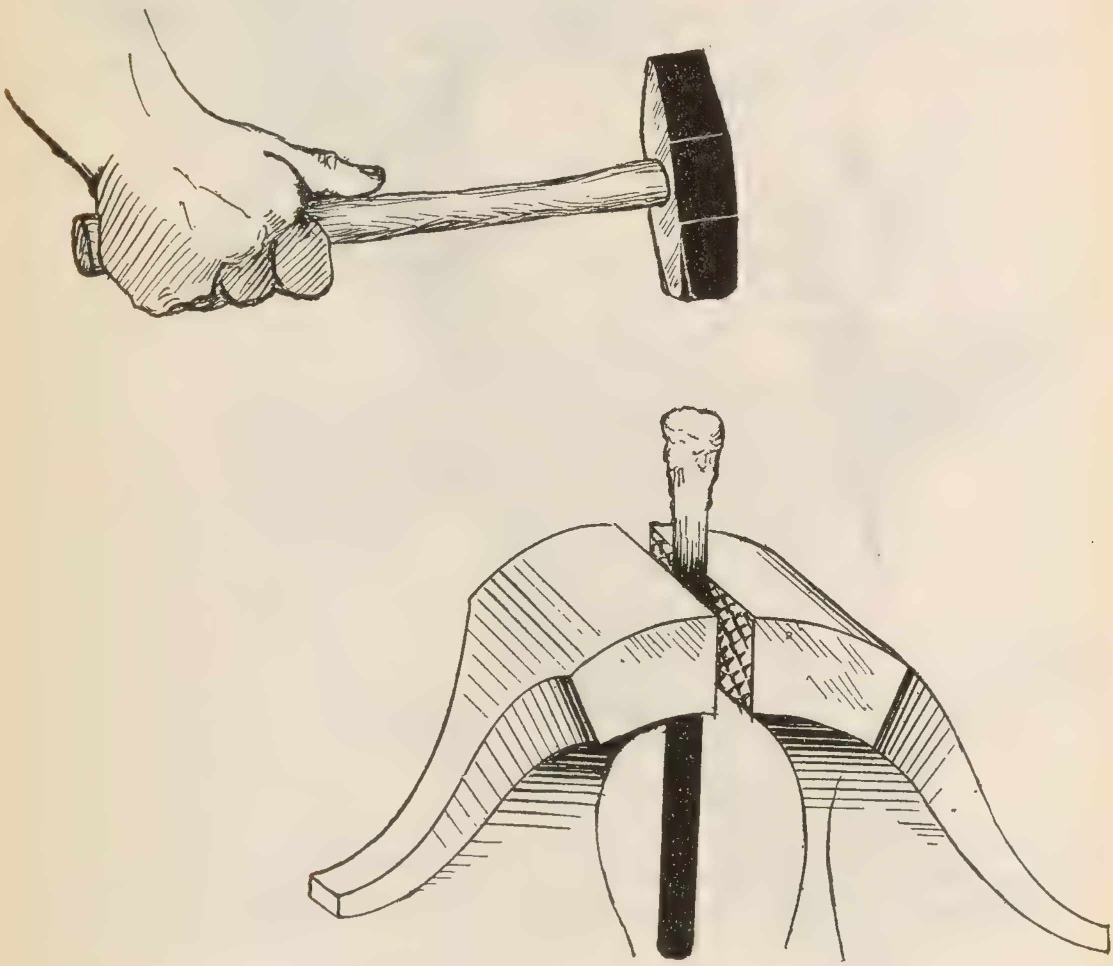


FIG. 9,960.—***Upsetting 3.*** By hammering (light bar). When the bar is too small to have any appreciable inertia effect it may be upset by placing in a vise and hammering.

may be welded without difficulty, being thus adapted for providing a cutting tip to tools and instruments which have to stand blows and jarring.

Set Temper.—Containing $\frac{7}{8}$ of 1 per cent. of carbon, this quality is well adapted for tools such as drifts, cold sets, etc., which have to stand

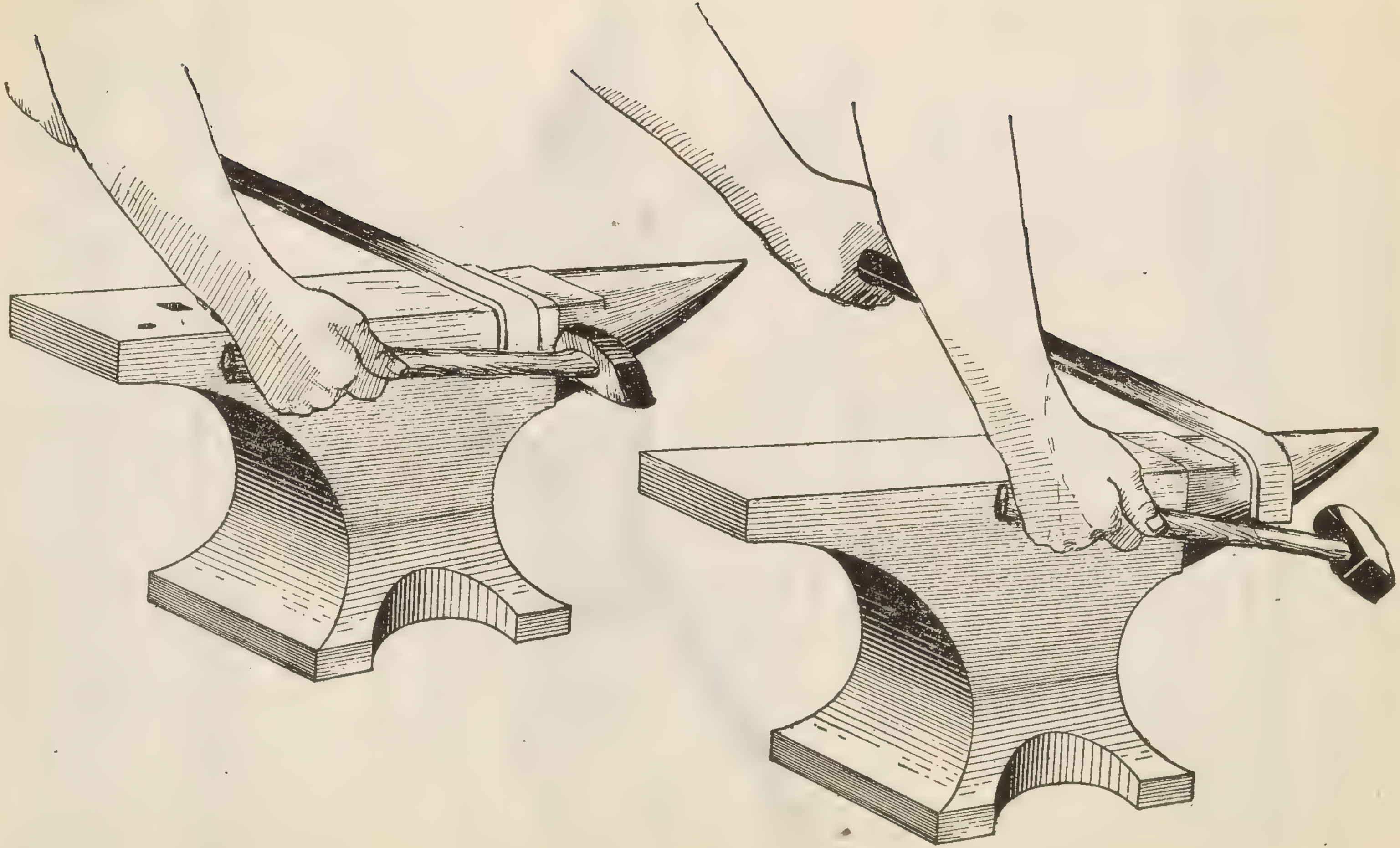


FIG. 9,961.—***Bending 1.*** Over rounded edge of anvil. For a very short bend, the stock is placed over the rounded edge of the anvil and hammered to shape as shown.

FIG. 9,962.—***Bending 2.*** Over anvil horn. Place stock over the horn at point where its curvature corresponds or approximates that required and hammer to shape.

their principal punishment on the unhardened parts. Can be welded easily by a toolsmith.

Die Temper.—This has only ¾ of 1 per cent. of carbon, and is the most suitable temper for such tools as dies for presses, rivet snaps, etc., where hardness is required only upon the surface, and the capacity of withstanding great pressure is of the utmost importance. This quality welds with freedom.

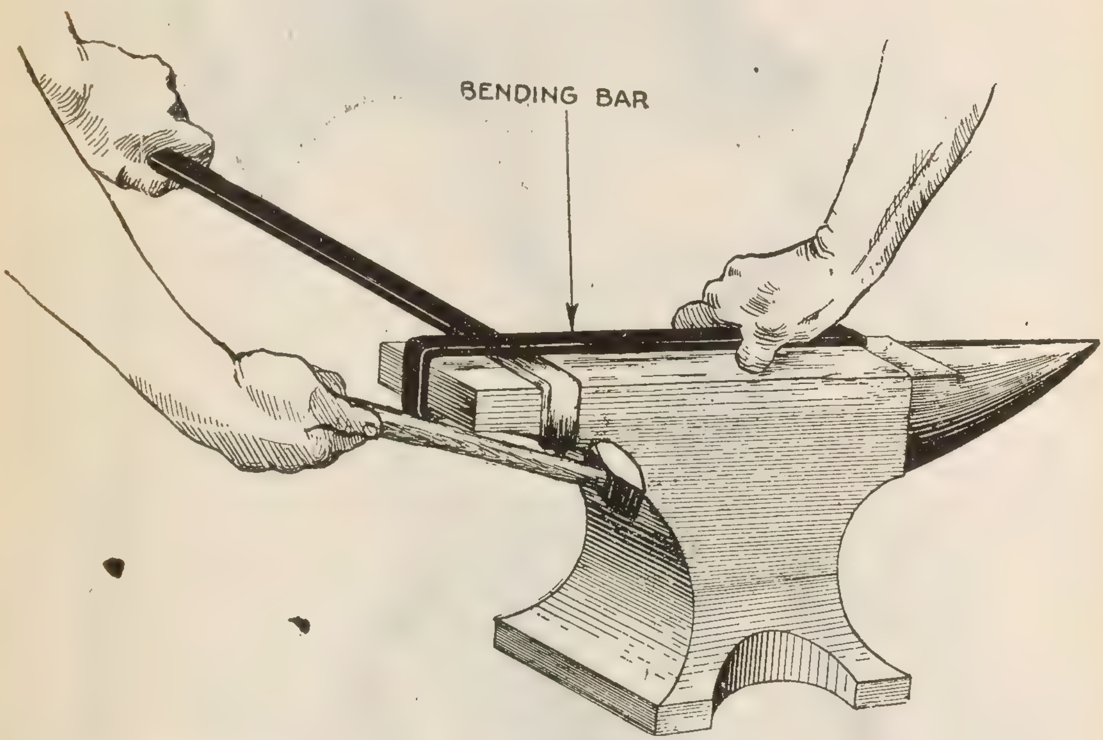


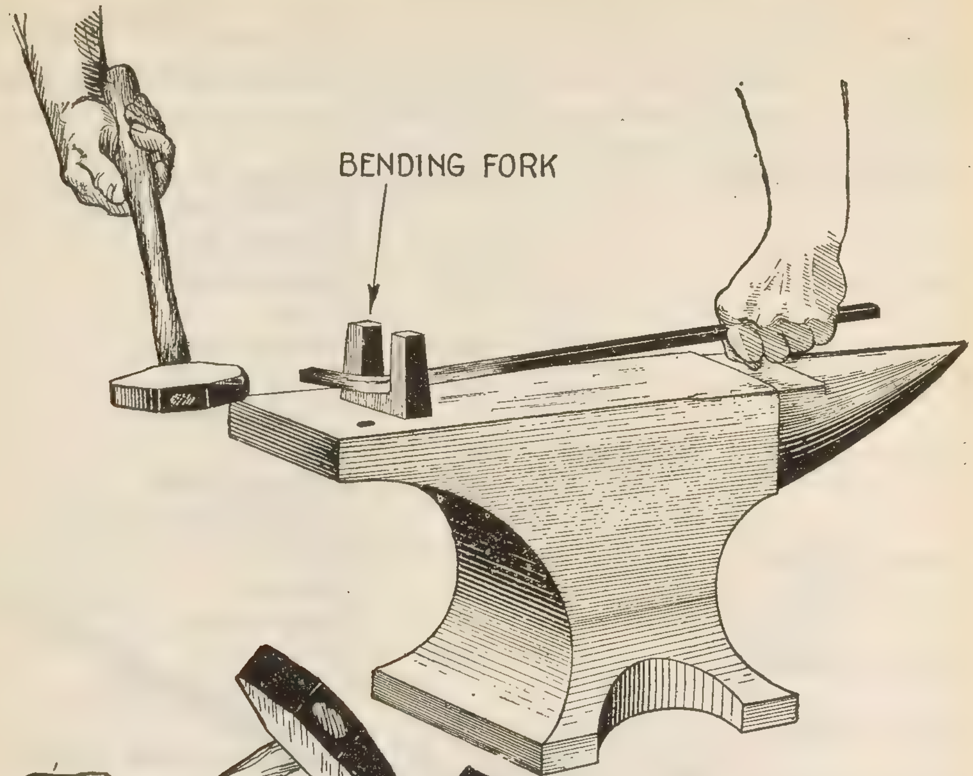
FIG. 9,963.—***Bending 3.*** Over sharp edge of anvil with bending bar. The stock may be held firmly in position with a bending bar, one end of which hooks around the end of the anvil and the other end pressed down firmly on the stock by a helper.

In the table following, tempering relates to the degree of hardness obtained by plunging the steel when heated to a cherry red, into cold water.

Table of Colors of Tempered Steel.

Colors	Temperature F.	Class of Tools for Which Used.
Very Pale Yellow	430°	Scrapers for brass.
		Light turning tools.
		Hammer faces.
Light Straw	450°	Plaining tools.
		Drills.
Medium Straw	460°	Milling cutters.
Full Straw	470°	Boring cutters.
		Screwing dies.
Dark Yellow	490°	Taps.
		Chasing combs.
		Punches and dies.
Yellow Brown	500°	Reamers.
		Gouges.
		Plane irons.
Purple Orange	520°	Twist drills.
		Flat drills for brass.
Light Purple	530°	Augers.
		Chipping chisels for steel.
		Axes and adzes.
Dark Purple	550°	Chipping chisels for cast iron.
		Firmer chisels.
		Cold sets.
Dark Blue	570°	Springs.
		Circular saws for metal.
		Screw drivers.
Middle Blue	590°	
Light Blue	610°	Saws for wood.
Greenish Pale Blue	630°	

Hardening and Tempering.—By definition, *tempering* means *the giving of any required degree of hardness to a piece of steel;* properly speaking, there are two distinct processes implied in the term, one being *hardening*, in which the steel is heated to a cherry red, corresponding to about 1,650° Fahr., and



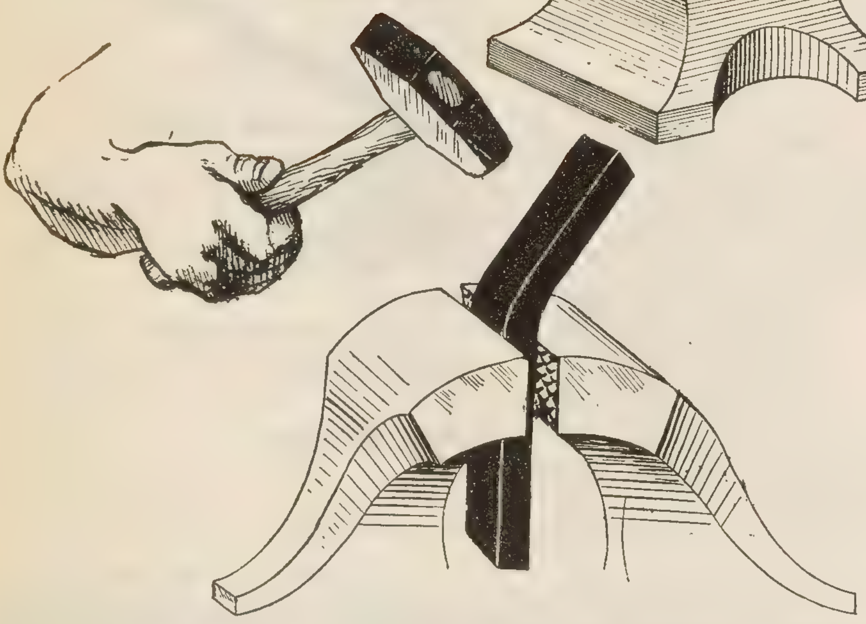


Fig. 9,964.—***Bending 4.*** With bending fork. The stock is placed in the fork at the point of the desired bend, and pressed firmly against the fingers of the fork in the direction indicated by the arrow. Thus secured, the stock is easily bent by hammering.

Fig. 9,965.—***Bending 5.*** In vise. In making a bend with the stock clamped in the vise it is important not to deliver the blows too close to the jaws of the vise.

plunged into cold water, making the steel hard enough to scratch glass. Next follows the second process of *tempering*, which must be performed to "draw the temper" to the proper degree.

In this, the steel *is reheated after hardening* until it attains the proper color, corresponding to its temperature, as seen in the preceding table. The steel is then plunged into water for the second and final time. The colors upon the surface

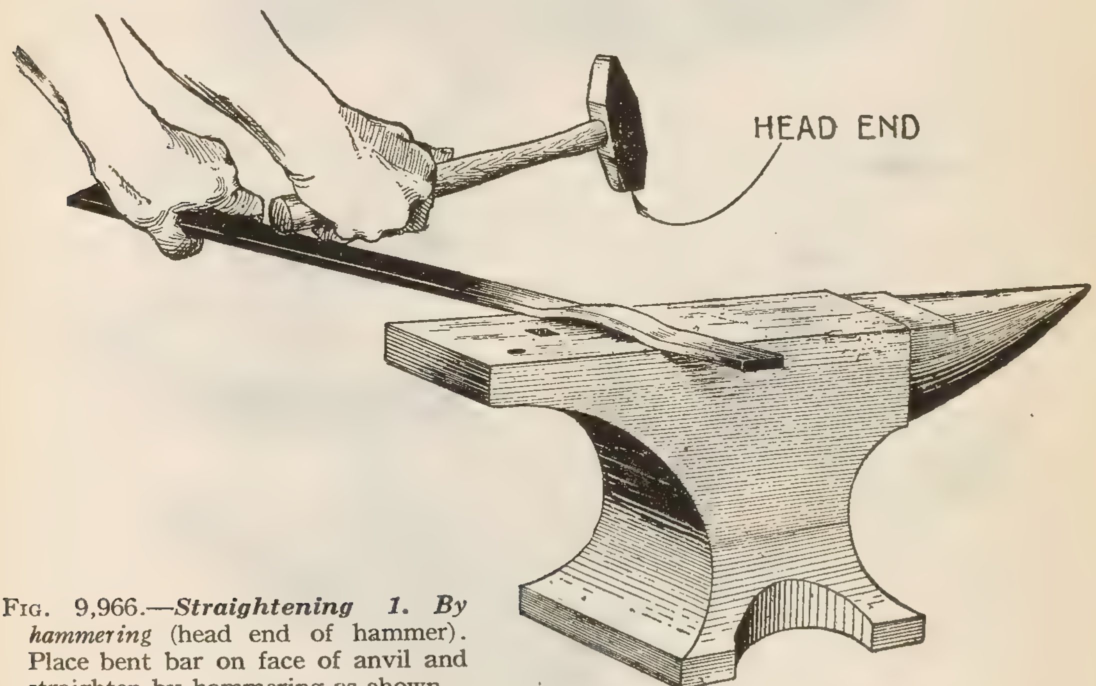


FIG. 9,966.—***Straightening 1. By hammering*** (head end of hammer). Place bent bar on face of anvil and straighten by hammering as shown.

of the steel are due to films of oxide of varying thickness, formed by the action of the air upon the metal. *When the quenching medium is water, the preliminary process of hardening must be carried out*, or else the act of tempering would be without effect.

The heating is best carried out in a clear coke or charcoal fire, or, if the articles be small, they may be placed within a D shaped muffle, or shallow sheet-iron box placed over the fire,

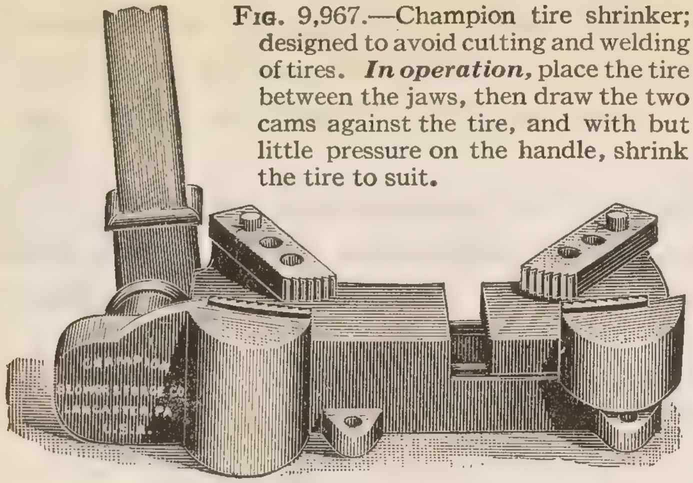


Fig. 9,967.—Champion tire shrinker; designed to avoid cutting and welding of tires. ***In operation,*** place the tire between the jaws, then draw the two cams against the tire, and with but little pressure on the handle, shrink the tire to suit.

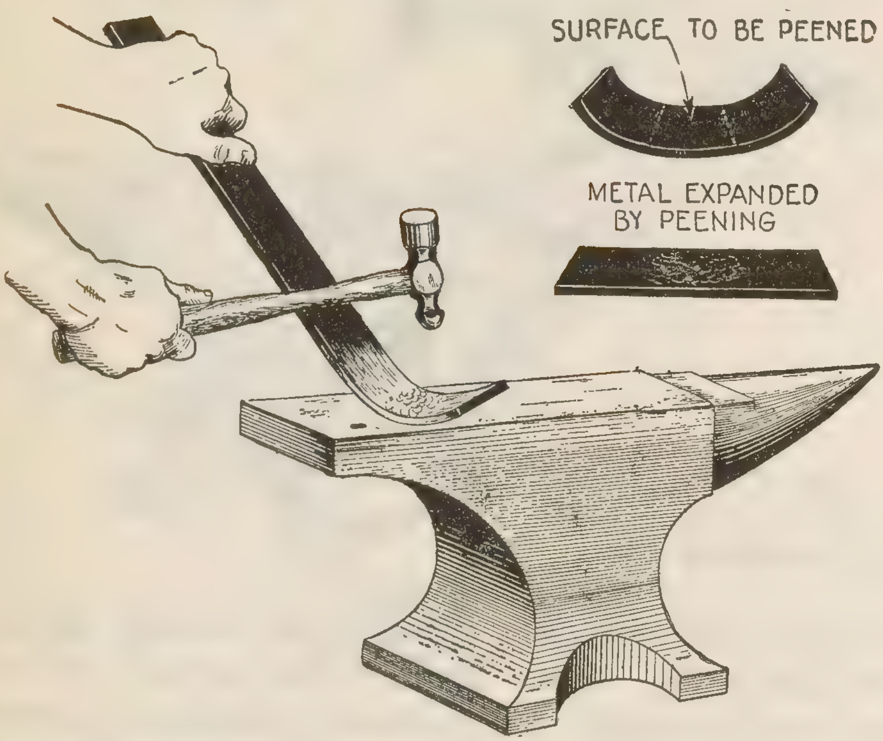


Fig. 9,968 to 9,970.—***Straightening 2. By Peening.*** This method is used in straightening thin flat pieces such as saws, knives, etc. The metal is struck with the peen of the hammer of blows distributed along the inner surface of the bend. The action is shown in figs. 9,969 and 9,970; it stretches the metal along the inside of the curve and consequently causes it to expand thus straightening the bar. To peen out a bad dent in an automobile body or fender. hold a hand anvil behind the dent, beginning at the outside edge of the dent and carefully work around the dent and in toward the center, thus gradually returning the metal to its original position.

to avoid formation of scale, unequal heating or discoloration of polished work; tool steel should be protected from the blast or draughts while heating or annealing, and the heat should be as uniform as possible over the whole of the article. This is

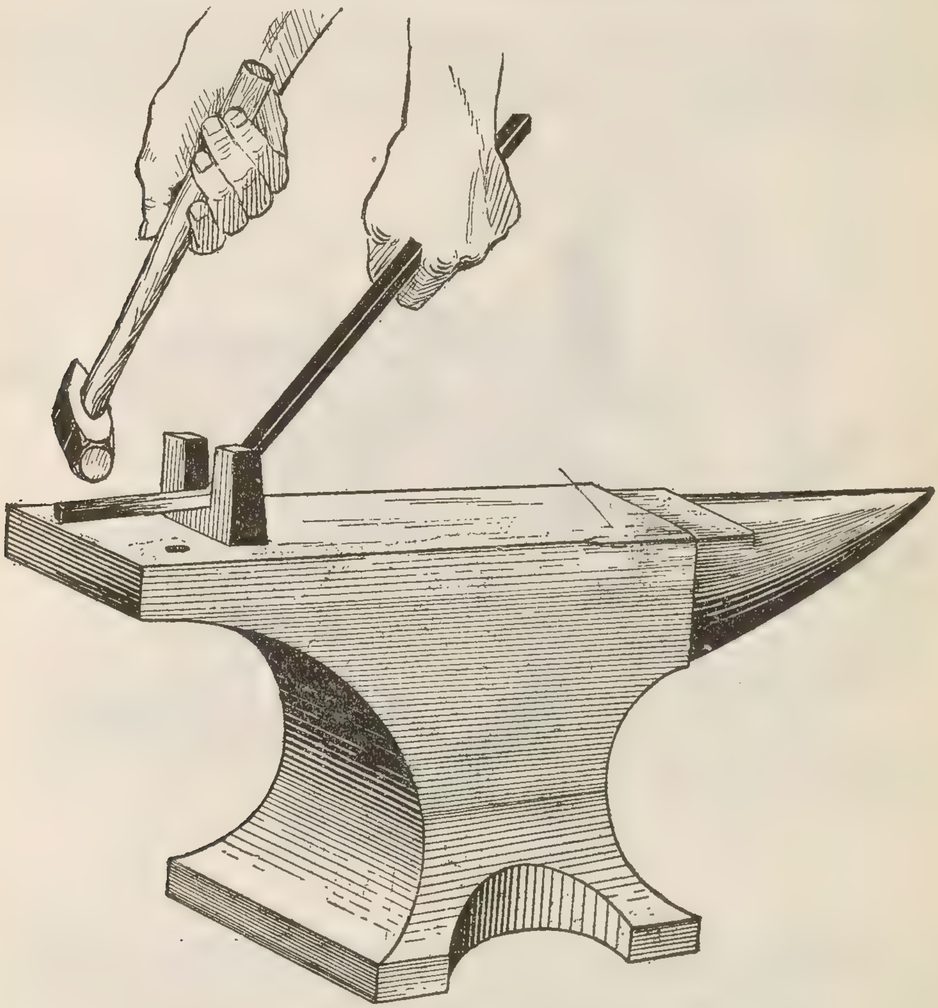


FIG. 9,971.—***Straightening 3.*** With bending fork. Place the bent piece between the fingers of the bar and straighten by hammering.

effected by moving it about through the fire, or, when a muffle is used, by turning the pieces around and over with the tongs.

If steel be exposed to too great a heat it becomes "burnt," and its quality is deteriorated. In view of this, until the quality of any particular steel becomes well known, it is wise to be even over-cautious in the

amount of heat applied. At the worst, the piece need only be re-hardened at a high temperature, whereas, if overheated, its quality will be permanently injured.

Tool steel showing a bright and granular fracture has probably been overheated; if not, it will be dark and even.

In view of the many reliable circumstances met with in tempering, it is frequently advisable to use a flux or bath in which the tool can be uniformly heated. The Waltham Watch Co. heat their hairsprings in molten

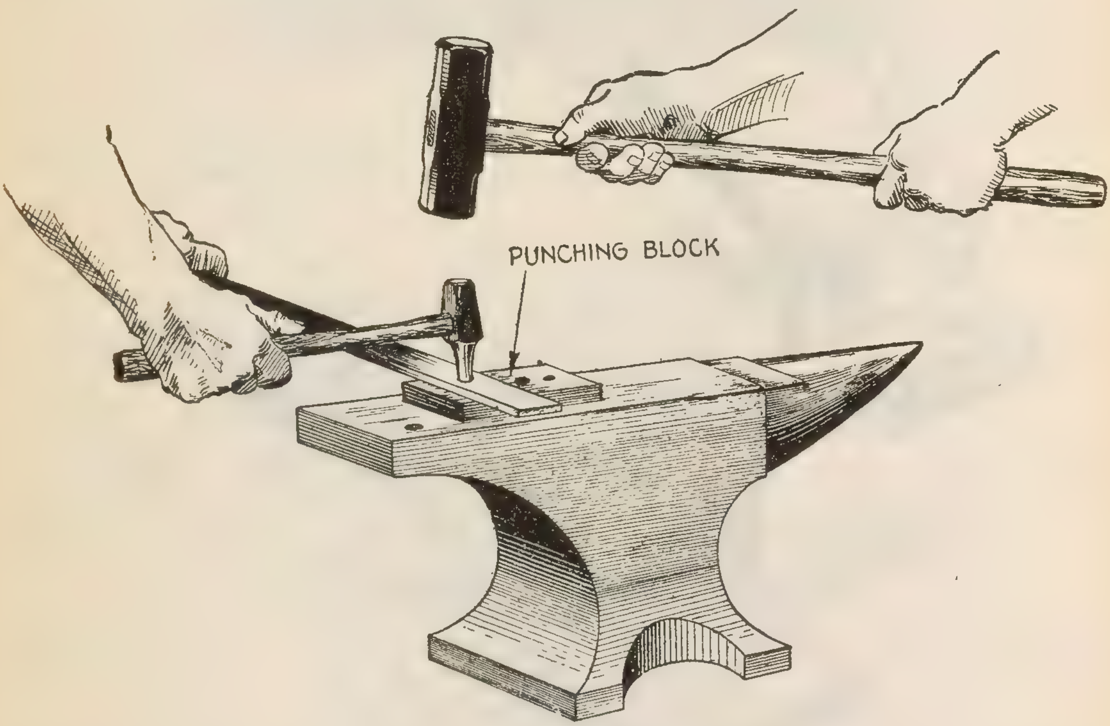


Fig. 9,972.—***Punching.*** Place punching block in hardy hole on anvil, locate work on punching block so that the disc or slug punched out of the metal will pass through one of the holes in the punching block. Hold work with one hand and punch with the other while the helper strikes the punch with a sledge as shown.

glass. Pratt & Whitney use an equal mixture of potassium cyanide and common salt for heating taps, as also do the Morse Twist Drill Co. for many of their specialties.

When an article is heated in a bath of molten lead, the surface of the latter being strewn with powdered charcoal to prevent oxidation, and then

tempered, the interior will be softer than the outside; this result is desirable for taps, reamers, etc.

The *cooling medium* used, it is well to bear in mind, influences the hardness of the temper; with *oil*, a species of tempering can take place *without preliminary hardening*, which is especially useful in dealing with large pieces, as not only does it harden the material, but may increase its strength while the uniformity of the process is assured. The articles are heated all over to a dull red heat, and then immersed in the oil, generally olive oil. Only one degree of hardness, that of a very dark straw color, can be obtained in

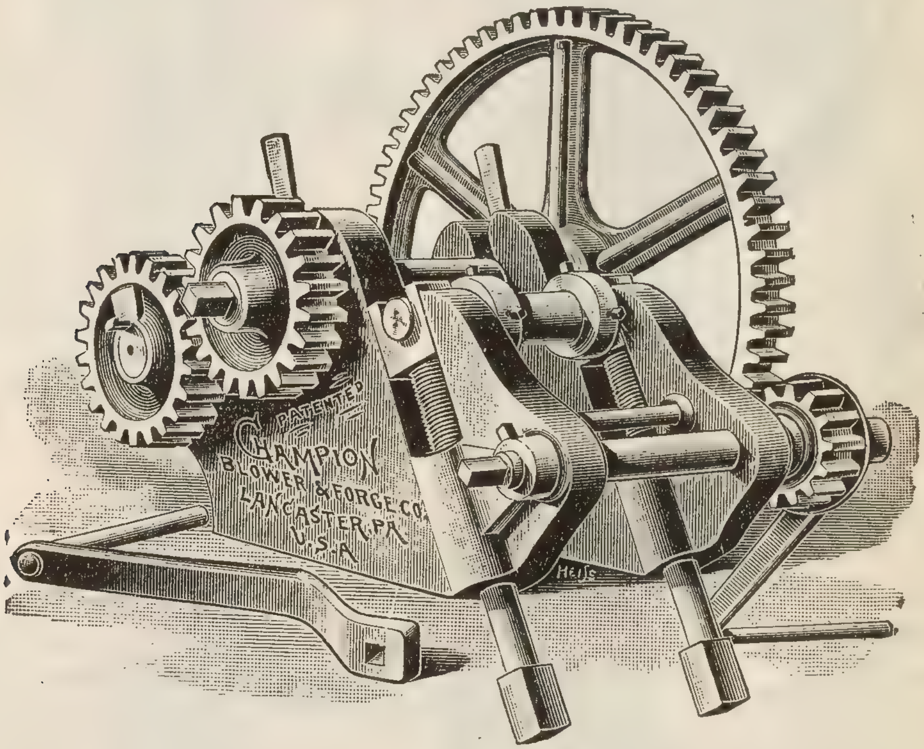
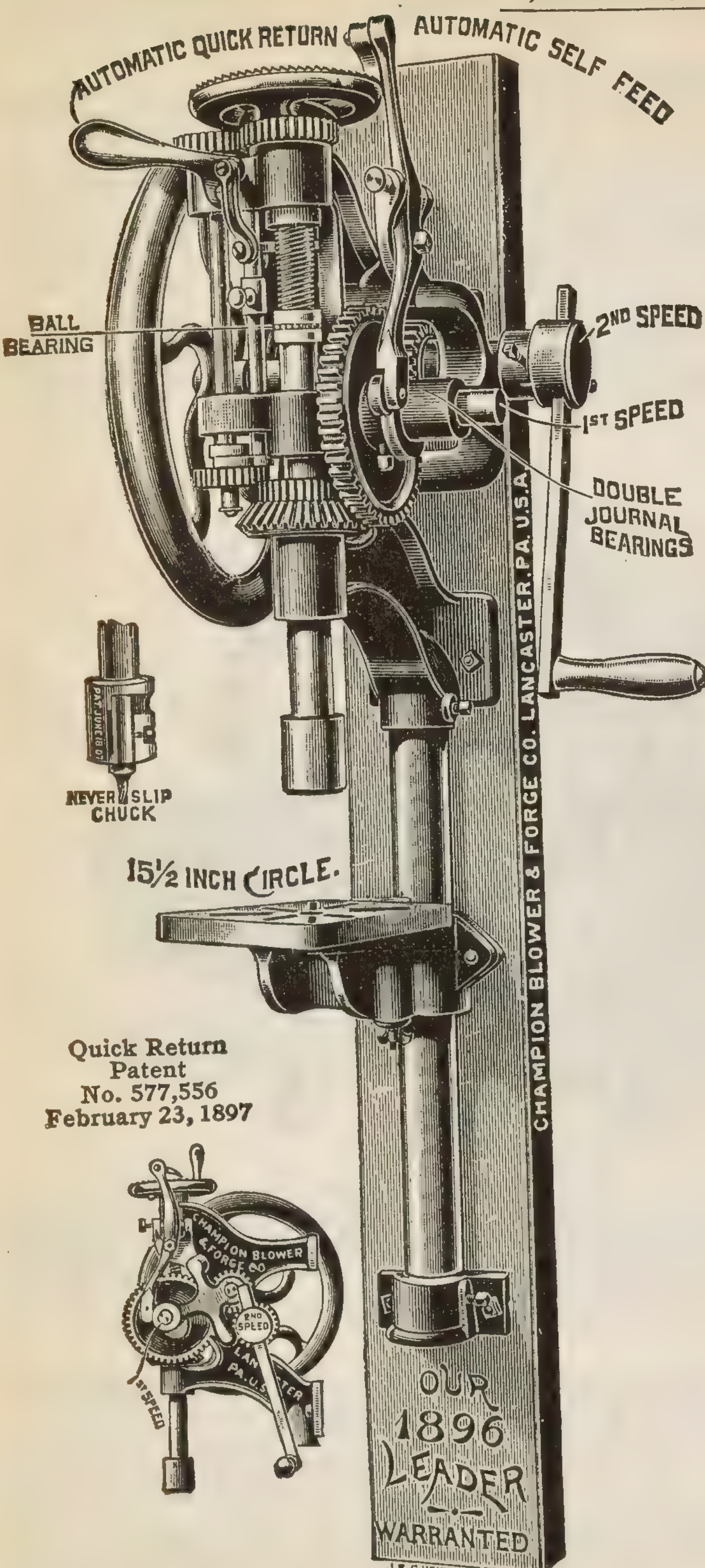


FIG. 9,973.—Champion "Eureka" tire bender. ***It is provided*** with adjusting screws at each end of the adjusting roll with a graduated indicator on each side of bender, showing the exact size of the tire being bent, giving the operator full control of the work. The two end rolls are provided with collars to prevent tire twisting so both ends meet when bent. It is double back geared, and worked with two cranks which are furnished with each bender; also two speeds, one for light and fast work, and the second for heavy work.

this way; but there is a more equable temper imparted for the same color than with water quenching, on account of slower cooling.

Plain water makes the best bath for all general purposes; the most favorable results have been attained with it at a temperature of about 40° Fahrenheit. Many tool smiths prefer to use the same water over and over again instead of changing it; but it is as well to keep it in circulation in the



Quick Return
Patent
No. 577,556
February 23, 1897

bath. A good plan is to admit a copious supply through a perforated false bottom, the excess of heated water escaping by a waste pipe near the top.

An oily film on the surface of the water will often save small articles from cracking, and will also take the chill off the water. *First hardening in water and then tempering in oil gives a superior softness to tools.*

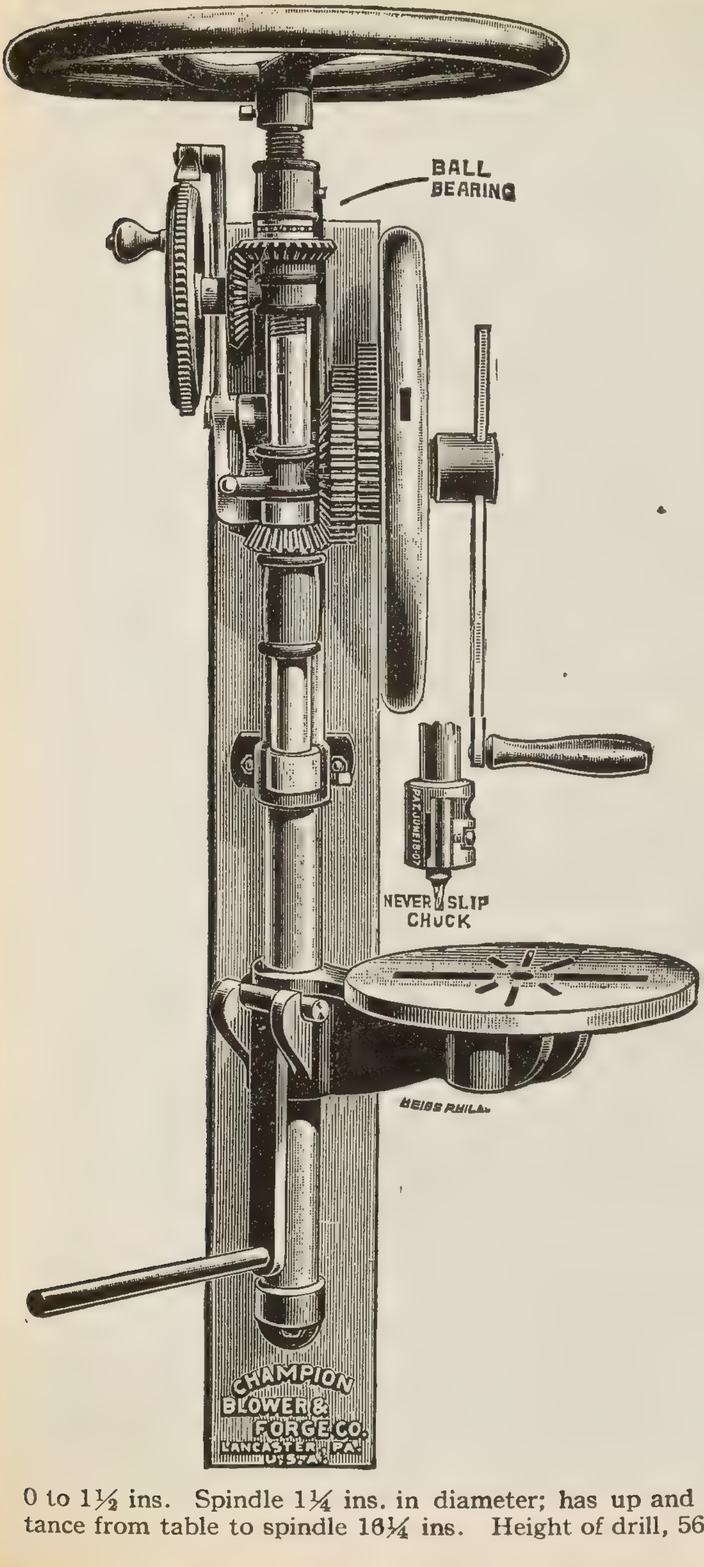
For harder materials *brine* may be used, composed of fresh water with enough salt added to float an egg, or half a pint of salt to one gallon of soft

Figs. 9,974 to 9,976.—Champion quick return self-feed post drill. ***It has*** three back gears with double journal bearings to each gear, in order to give second speed same turning direction of the crank as the first. Spindle has end thrust ball bearings. The quick return lever is thrown into place while the drill continues in motion, where it remains until the bit is raised out of the work and automatically stops, requiring no attention from the operator, and is again ready for the next hole. Drills holes from 0 to 1½ ins. Spindle 1⅛ ins. in diameter; has up and down run of 3 ins. Greatest distance from table to spindle, 9 ins. Height of drill 46 ins.

water. A *mercury* bath is supposed by many to make the hardest grade of steel, but if the very hardest possible point is wanted on a steel tool, its point should be brought to a cherry red and then be thrust into a solid block of *lead* until cooled.

In tempering tools, it is always advisable that the parts should be ground or machined to a surface beforehand, as the natural skin of the metal gives false colors.

Unequal heating is as much responsible for the cracking of milling cutters, pipe cutter wheels, etc., as unequal cooling, and to avoid this the process of heating in a bath of molten lead maintained at a high temperature has been successfully tried.



FIGS. 9,977 and 9,978.—Champion "Black Diamond" self-feed post drill. The side fly wheel in connection with the top fly wheel is very practical, when taken into consideration, that both the fly wheels make two revolutions to each turn of the crank. It has two speeds. Crank turns same direction on first and second speed. Spindle has end thrust ball bearings. Drills to the center of an 18 in. circle. Drills holes from 0 to 1½ ins. Spindle 1¼ ins. in diameter; has up and down run of 4 ins. Greatest distance from table to spindle 16¼ ins. Height of drill, 56 ins. Weight 215 lbs.

When dipping these articles it is wise to sling them from a wire threaded through the holes and having its ends twisted over a small rod to carry or suspend it, the hole being filled with fire clay. This prevents cracking at the central hole.

Toothed drifts for cutting out long narrow holes should be tempered all over to a purple blue; those of stouter proportions can be made of a brown purple.

Taps require to be softer at the shank than at the teeth to avoid breaking off in use. A neat way of effecting this is to procure a piece of iron tube, just a shade larger than the tap, and a pair of round bit tongs as shown in fig. 9,878. After the tool is made and polished it is first hardened, and then the temper is lowered in the following manner: The preliminary heating being done in a muffle or on a plate, to avoid discoloration, the tongs, which have been made bright red in the fire, are used to grip the tap by the shank, to bring the color down. Meanwhile the piece of pipe has been brought to a *dull red*. As soon as the first signs of straw color appear on the shank, from the heat of the tongs, the tap is thrust into the tube up to the end of the threads. This keeps the color back on the screwed portion, and the shank will be dark blue by the time the threads have reached dark straw, when the whole can be plunged into the water. It is, of course, necessary to employ long-nosed tongs, to heat the whole of the shank.

The countersink is used for enlarging orifices, such as are employed for rivet holes requiring to be flush or even with the surface of the riveted plate. In tempering these tools or any others having a pin or projection to serve as a guide in the hole, it is necessary that the pin or teat working in the hole should be much harder than the cutting edge. It is therefore customary, first to harden the tool fully, dipping it gradually into clean water to avoid cracking, and then lower the hardness to the requisite temper by heating the tool upon a bar of red hot iron.

As soon as the pale straw color has come down to the pin, it must be kept in that state by directing a little stream of oil upon it, while the color "comes down" to the required shade on the main part of the tool, plunging it into clean water as soon as that stage has been reached.

Thermal Critical Points of Steel.—If one should watch the slow heating of a piece of steel in a furnace, it would be noted that the temperature of the steel gradually increases with the increasing heat of the furnace until a temperature is reached when the steel may become slightly darker and cooler than the furnace.

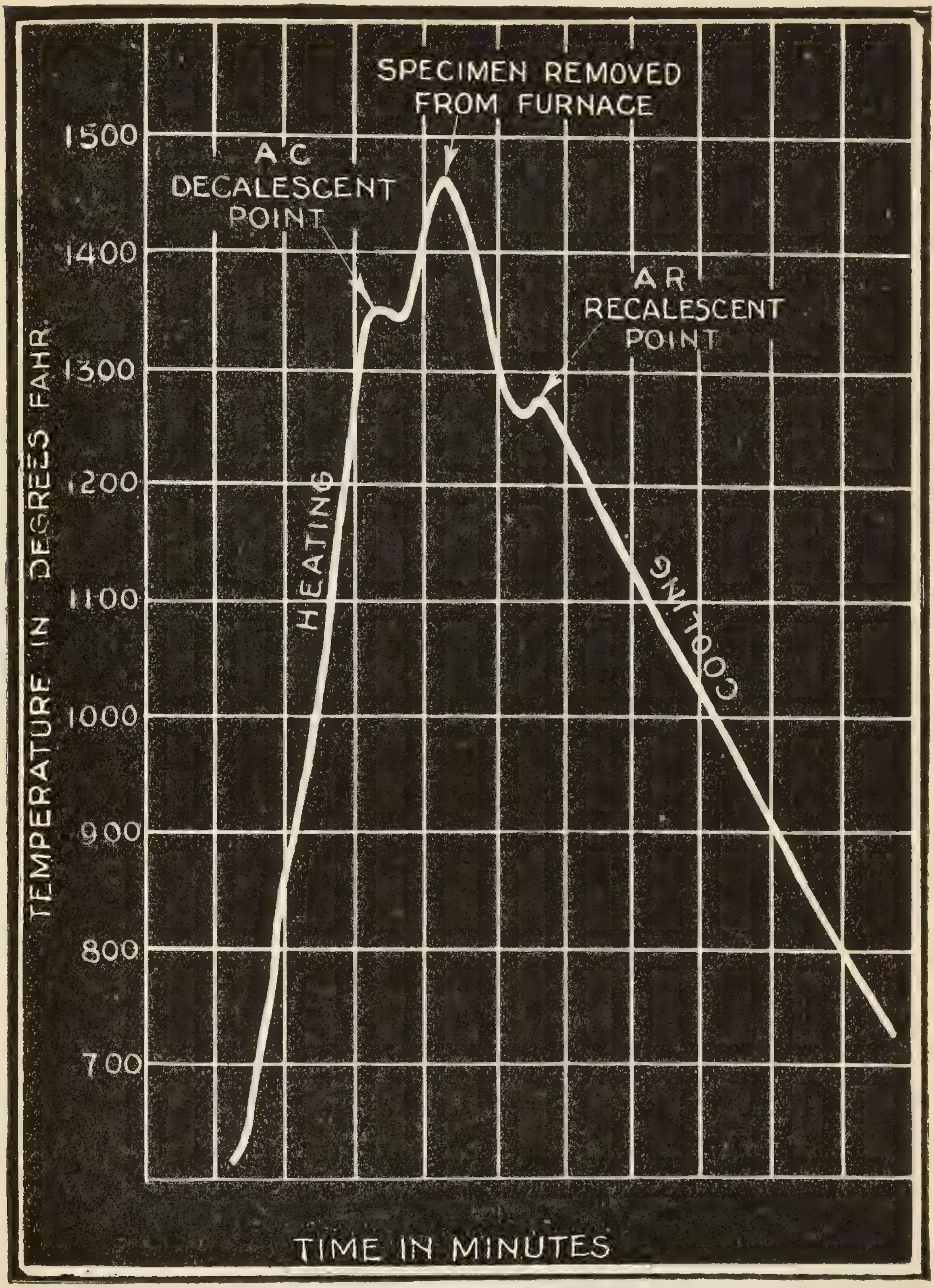


FIG. 9,979.—Critical points in the heating and cooling of steel.

As the heating is continued the piece will again assume the temperature of the furnace. In the rising heat the darkening of the piece of steel is due to the absorption of heat to convert ferrite and pearlite into austenite. Now if the furnace be permitted to cool slowly during some point in the process the steel may become brighter or visibly hotter than the furnace, after which it assumes its normal rate of cooling which continues on down to atmospheric temperatures. Such a rise in temperature in a slow cooling indicates a giving off of heat during the conversion of the austenite back to ferrite and pearlite.

A transforming of the constituents composing the steel accompanies these thermal changes as, for example, on heating, the decomposition of ferrite and pearlite.

To form austenite as mentioned above or vice versa, the decomposition of the austenite into its constituents, ferrite and pearlite, as the case may be, during slow cooling. The temperatures or points where these changes take place during the heating and cooling are called the critical points of steel.

To distinguish these two points, or ranges as is actually the case, those occurring on the heating are termed "Decalescence" and those on the cooling "Recalescence" points. These terms are usually noted by the symbols Ac for "Decalescence" and Ar for "Recalescence." When the various critical points occurring in steel are considered collectively, the range of temperature that they cover is called the critical range. The meaning of the expression "critical range on heating" and "critical range on cooling" is obvious.

CHAPTER 152

Brazing

By definition brazing is *the art of uniting metals by means of a hard solder*. Originally, as its name implies, it was devoted to the union of brass or other copper alloys.

The theory of brazing is *the melting of a low fusing metal against the metals to be united while they are in such a condition of cleanliness* **and temperature** *that the metal welds itself to them.*

Brass filings have been generally replaced by *spelter*, which is a composition of about equal parts of copper and zinc; this is used for brass work. For tubes, a composition of 8 parts of brass tube filings to 1 of zinc is used.

Brass or gun metal united by this process will produce a joint as hard as the metal pieces united.

Iron and steel, especially small pieces of finished work, may be united, by the same means. The process of brazing consists essentially of

1. Cleaning the parts to be brazed;
2. Applying the hard solder and flux;
3. Heating.

The work is first carefully cleaned with acid, and some fine spelter is mixed with borax to form a flux, a little water being added to make a paste. The compound is placed between the parts to be united, as much surface as possible being brought in contact, the two being held firmly together, in the case of small pieces by tongs, and heated until the flux

and spelter are melted, the parts being held together until the spelter unites with the metal and solidifies.

Sometimes the work cannot be easily gripped, and so, after inserting the spelter and borax as before, the parts are bound with iron wire and placed in a clear coke fire until the operation is complete. The superfluous metal around the joint will in each case need to be removed by means of the file.

There are various methods of brazing; such as

1. Butt brazing;

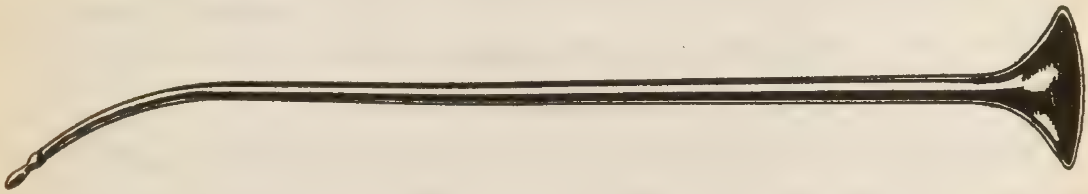


FIG. 9,980.—Ordinary mouth blow pipe.

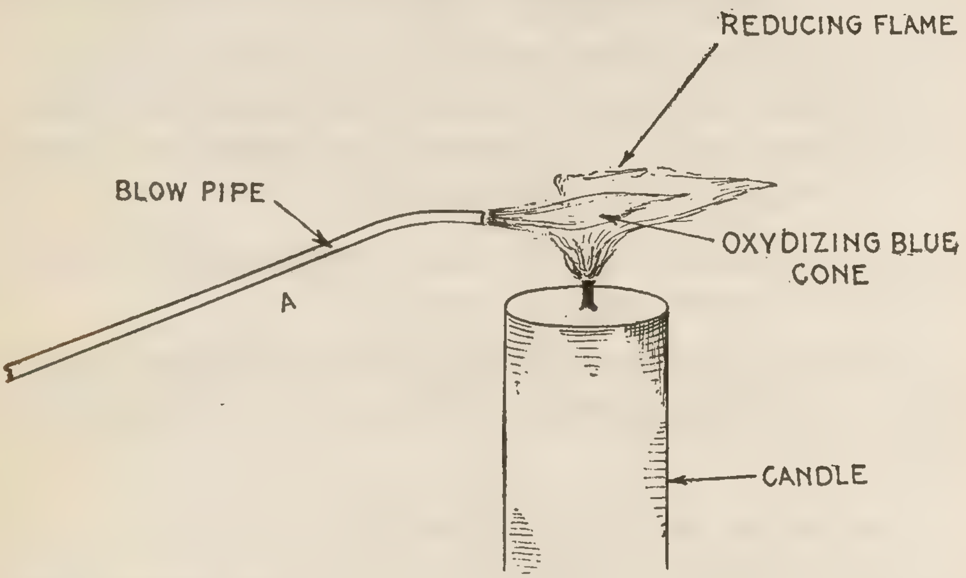


FIG. 9,981.—Method of using the mouth blow pipe. This is for small work, though the intensity of the heat thus produced is very great, the volume of flame is small. On some blow pipes a ball or enlargement is made at A, to catch any moisture or saliva, thus increasing the efficiency of the instrument. The torch as shown, gives two flames as follows: ***1, oxydizing flame,*** commonly caused by the chemical uses of oxygen with another substance. If more oxygen be supplied than is needed for perfect combustion, the free oxygen in excess makes an oxydizing flame, one that rusts or burns the metal. A flame may be oxydized in one place and reducing in another; ***2, reducing flame,*** defined as a flame in which the fuel is in excess of the oxygen necessary for perfect combustion. *The tendency of such a flame is to draw some oxygen from the burned parts of the metal.* It prevents burning within its radius.

2. Lap brazing;
3. Dip brazing;
4. Muffle brazing.

Butt Brazing.—This method consists of placing the two pieces to be brazed *butt to butt*. If two thin pieces are to be butt brazed, the pieces must be held in position in a bench vise, or

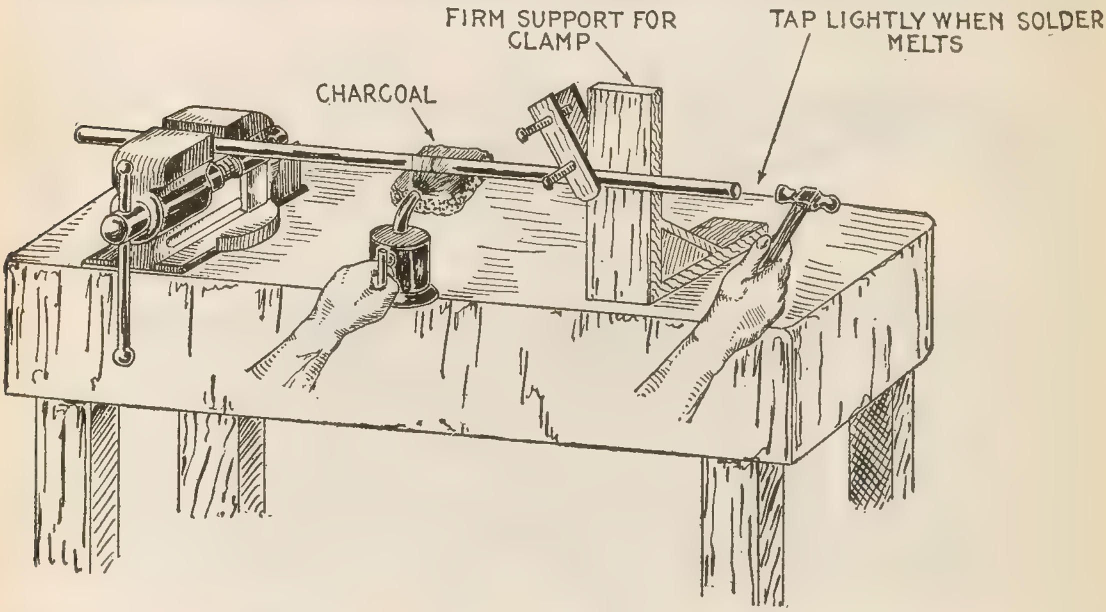


FIG. 9,982.—Butt brazing two lengths of small pipe. After cleaning the ends to be brazed and fluxing, they are clamped in position butt to butt using a vise and clamp as shown, or other means. A little brazing solder is sprinkled over the joint and heat applied. When the pieces are hot enough to melt the solder it must flow into the joint, butt brazing the two pieces. By giving one of the pieces a slight tap on the end, when the solder melts, the surplus solder is squeezed out, making a good and firm joint. If the pipes be large or of considerable length, the heat is quickly conducted away, necessitating a charcoal backing or more adequate means of heating.

clamp, and the heat applied with a torch or blow pipe. The surfaces to be brazed are fluxed and then clamped in position and the proper hard solder, as given in the tables, applied.

Heat is then applied by means of a blow pipe. or Bunsen burner, until the pieces are hot enough to melt the solder, which will then flow into the crack.

By giving one of the pieces a slight tap on the end, they are brought tightly together. After cooling, the superfluous solder is scraped off.

Lap Brazing.—In this method the parts to be brazed are overlapped. Band saws are always lap brazed, the two ends being filed to make an accurate joint. Silver solder is generally used, it being applied between the two surfaces, or the surfaces

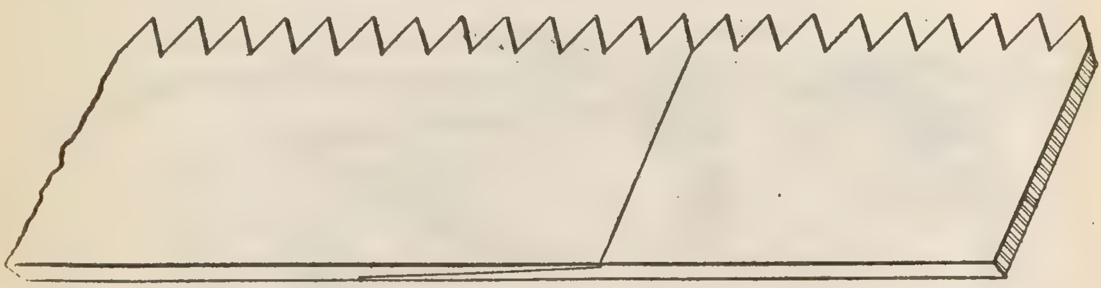


FIG. 9,983.—Lap brazing. A band saw is a good example of this method. In making the lap the two ends are chamfered by filing to make an accurate joint as shown. Silver solder is generally used, it being applied between the two surfaces, or the surfaces are coated with borax and the solder allowed to flow into the joint from the edges. After firmly clamping the parts in position, the solder is laid over the joint, or it may be placed between the two pieces to be united. When the heat is applied, the solder melts and the two pieces must be squeezed tightly together to force out surplus solder. Silver coins contain 10 per cent. of copper and make a good hard solder. When using a coin, pound it until very thin and then place between the two surfaces to be brazed.

are coated with borax and the solder allowed to flow into the joint from the edges. The operation of lap brazing a saw is shown in fig. 9,983.

NOTE.—*Cast iron soldering.*—A new process consists in decarbonizing the surfaces of the cast iron to be soldered, the molten hard solder being at the same time brought into contact with the red hot metallic surfaces. The admission of air, however, should be carefully guarded against. First pickle the surfaces of the pieces to be soldered, as usual, with acid, and fasten the two pieces together. The place to be soldered is now to be covered with a metallic oxygen compound, and any one of the customary fluxes, and heated until red hot. The preparation best suited for this purpose is a paste made by intimately mingling together cuprous oxide and borax. The latter melts in soldering and protects the pickled surfaces, as well as the cuprous oxide from oxidation through the action of the air. During the heating the cuprous oxide imparts its oxygen to the carbon contained in the cast iron and burns it. Metallic copper separates in fine subdivision. Now apply hard solder to the place to be united, which in melting, forms an alloy with the eliminated copper, the alloy combining with the decarburized surface of the cast iron.

Dip Brazing.—This consists of dipping the work into molten solder until the parts are heated sufficiently to be united by it. For duplicate work this method is well suited, and is extensively employed in bicycle manufacture.

Muffle Brazing.—As indicated by the title, a tube or *muffle* is used in this method for enclosing the parts to be brazed. The object of the muffle is to insure uniform heating; it is

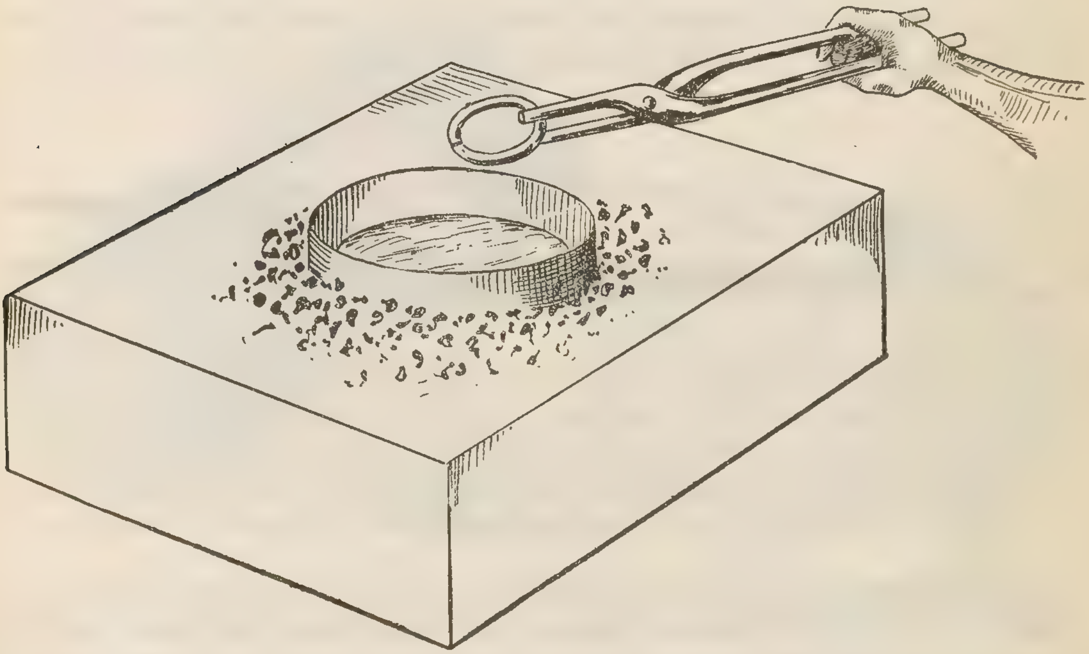


FIG. 9,984.—Brazing by immersion or dipping. The brazing solder is melted in a pot on the coal fire, as shown, or better in a gas furnace, flux being placed on top of the solder. *In brazing,* hold the object first in the flux a little while to heat and coat the article with a film of flux. Then, when it is lowered into the solder, the latter will flow in the joint and firmly attach itself. Before dipping, the article to be brazed is coated with a special anti-flux graphite, covering all the surface except that which is to be brazed. The layer of flux in the pot may be kept from ½ inch to 2 inches deep.

especially adapted to brazing alloys, the melting temperature of which are rather close to that of the solder.

Brazing of Copper.—For coppersmith's work the joints are

prepared either by *thinning* or *cramping*. The first process consists simply of scarfing the edges to a long bevel, and is used for heavy material only. The second, a necessity for lighter work, is rather more elaborate; notches are cut at a slight angle into one of the edges to be united, and the teeth thus formed are bent alternately to left and right. The edge of the other piece is thinned and inserted between the cramp, so that alternate pieces come on opposite sides of the thinned edge, supporting it.

Copper joints to be brazed are cleaned by covering the parts with a strong brine made from salt and water; they are then heated to a cherry

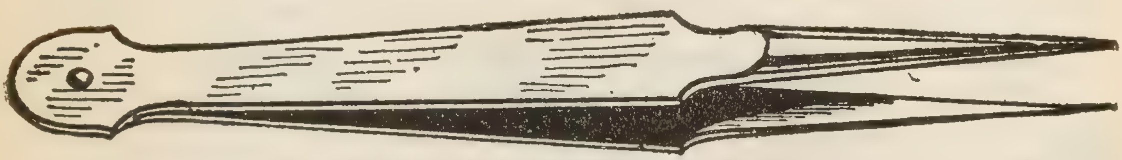


FIG. 9,985.—Brazing the joint of a pair of tweezers. The surfaces to be brazed are cleaned, some of the spelter applied to each surface, and the pieces tied together with a fine iron wire and heated sufficiently to melt the spelter. The heat may be applied with a blow pipe or by holding the pieces in a pair of hot tongs. When the spelter is melted the piece is cooled and the iron wire is taken off. When the pieces are clamped in hot tongs, the iron wire is sometimes omitted, the pieces being placed in their proper relation and the tongs depended on to keep them there, or stops may be arranged to determine the location of the pieces.

red and plunged into clean fresh water, which also has the effect of annealing the copper. Scouring follows with clean water and sand rubbed on with a wad of tow.

The brazing mixture is made of borax and spelter in equal parts, with water, and is preferably made a day or two previously The prepared portions of the article to be joined are placed together and fastened, if for pipe, by being bound with iron wire. The overlapping edges are closed by means of a mallet on a stake or mandrel.

The mixture is then laid evenly along the joint, and the pipe or other article placed upon a clear coke fire, the temperature of which is easily regulated. Presently, the borax fuses and forms into *drops*, and then the solder melts, which is indicated by blue fumes from the zinc. Probably it will be necessary to sprinkle a little more powdered borax, and the pipe may have to be tapped with a mallet or hammer to cause the

lapped parts to open slightly and permit of the solder flowing readily in between them. Salt is often strewn on the surface immediately after the solder has run, to kill the borax, as it would leave a hard scale interfering with future filing.

All flanges to be brazed to copper pipes must be of copper or what is known as brazing metal, 98 copper to 2 of tin, as gun metal flanges would melt before the spelter ran.

The hole in the flange is slightly tapered, and the end of the pipe, also, to form a clearance in which the spelter may flow, a countersink being also formed in the face side of the flange, and the pipe slightly opened to fit it.

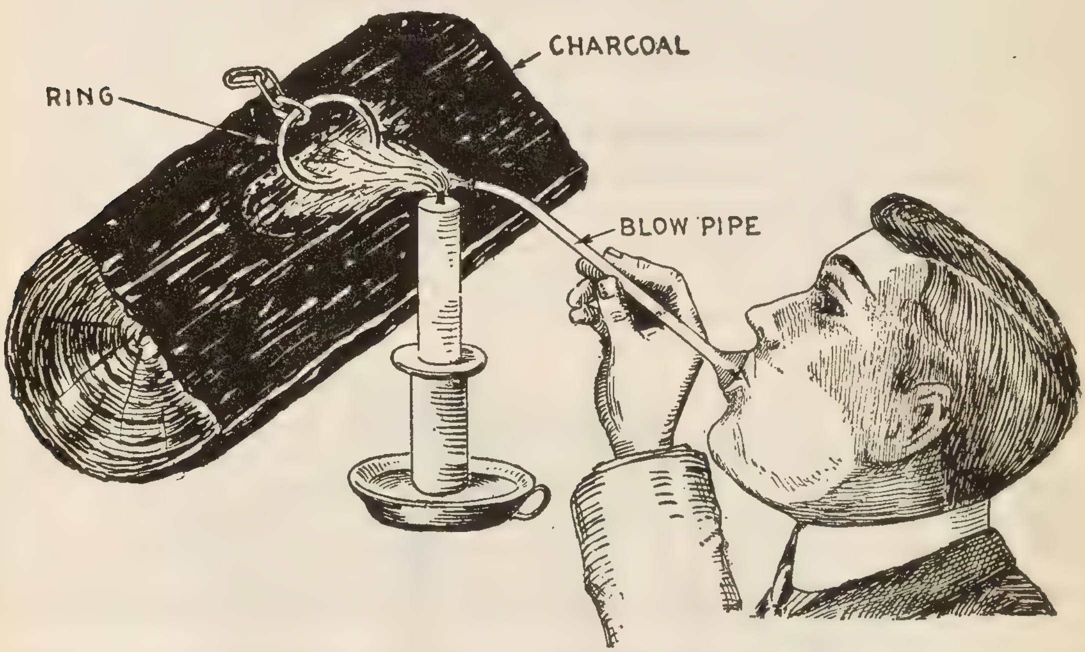


FIG. 9,986.—Brazing a small chain link in charcoal with a blow pipe. Place the broken link in a small hole scooped in the charcoal and heat with the candle flame and blow pipe after applying the solder and flux.

After the mixture is placed in the joint and the parts put together, the countersink is stopped with clay, to retain the solder. The pipe is then slung vertically over the fire, with the flange underneath, and the previous process carried out.

It will frequently be necessary to close the pipe with a clay tamping or a wooden plug to prevent the heat from going up it. Projections from flanges are protected from the fire by means of a covering of clay.

Table of Brazing Solders

Description	Copper	Zinc	Tin	Lead
Coppersmiths' strong spelter	75	25		
Coppersmiths' spelter	58	42		
Ordinary refractory spelter	50	50		
Hard white solder	57½	28	14½	
Half white, easily fusible	44	50	4½	1½
Spelter, readily fusible	33⅓	66⅔		

A few additional brazing solders are here given with their characteristics and colors.

Miscellaneous Brazing Solders

PERCENTAGE				Characteristics	Color
Copper	Zinc	Tin	Lead		
58	42			Very strong	Reddish yellow
53	47			Strong	Reddish yellow
48	52			Medium	Reddish yellow
54.5	43.5	1.5	0.5	Medium	Reddish yellow
34	66			Easily fusible	White
44	50	4	2	Easily fusible	Gray
55	26	15	4	White solder	White

Heating Methods in Brazing.—On account of the higher temperature required in brazing, a flame is generally used instead of a heated bit. For small work a blow pipe or torch is used, and a forge for large work. A torch alone is ordinarily insufficient as the heat must be put where it is needed and held there. This is usually done by building around the work with charcoal which becomes incandescent from the heat of the gasoline flame, and also gives off some heat from its own combustion.

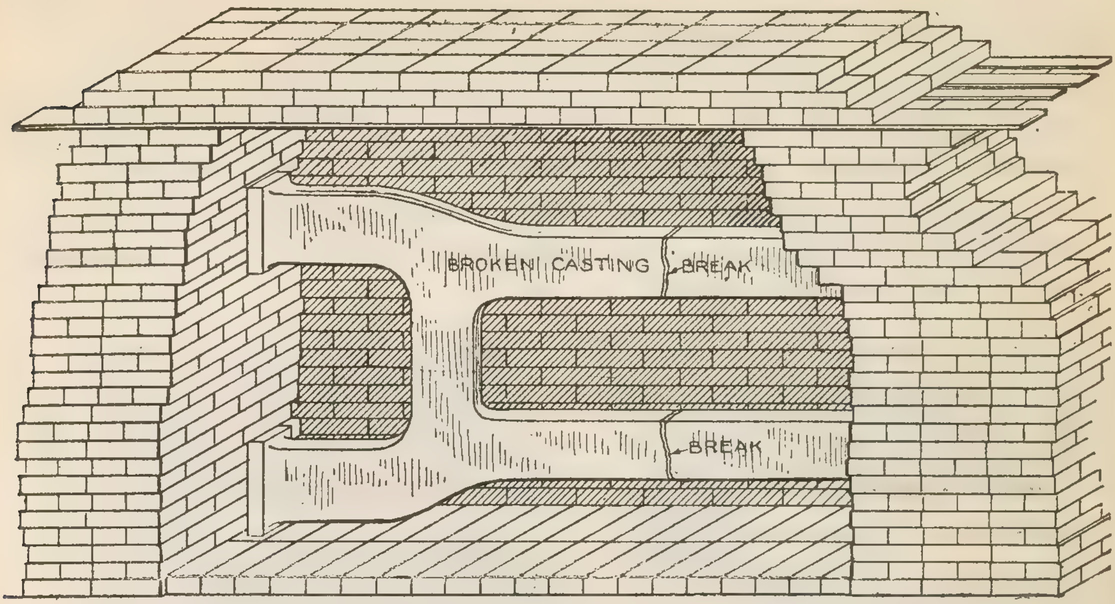


FIG. 9,987.—Quickly constructed furnace for brazing; view showing broken casting in position ready for brazing.

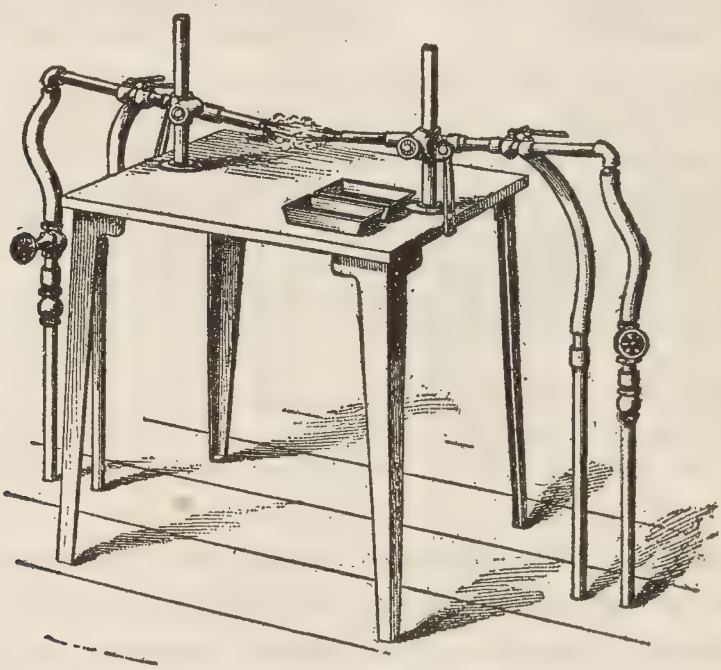
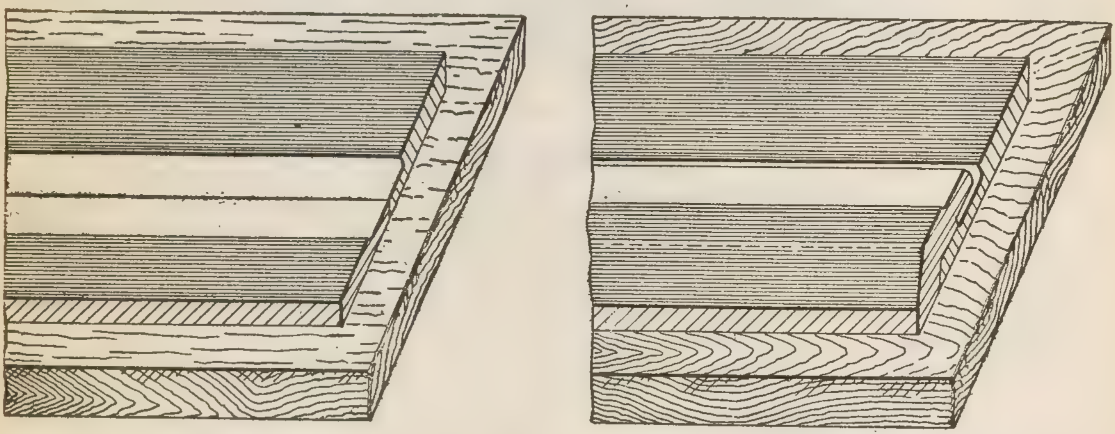


FIG. 9,998.—Brazing furnace without fire bricks. At opposite sides of the top are standards upon which sleeves freely slide, and which are held at any desired height by thumb screws. Each sleeve carries a burner to which gas and air pipes are connected, each pipe being provided with a valve for regulating the flow. The two burners can thus be adjusted so that the meeting points of their flames will be at any desired height above the table.

If the article to be brazed be very small, it can be placed bodily in a hole scooped in a bit of charcoal as shown in fig. 9,986.

In brazing in the smith's forge it is well to hold the work high up, so that it does not rest on the coal, but is kept suspended between banks of incandescent fuel so that the heating will be as near uniform as possible.

A charcoal fire should be used, but if bituminous coal be used, coke enough of it to do the work, as the sulphur in the soft coal is to be avoided where good brazing is desired.



FIGS. 9,989 and 9,990.—Preparation of butt and lap seams for lead burning. Fig. 9,989 shows the edges of a butt seam placed together on a piece of flat board, and the seam shaved ready for burning. The width of the shaving is governed by the thickness of the lead to be joined. For 5 lb. lead the rear should be about ⅜ inch wide, that is the edge of each piece should be shaved to a width of $^3/_{16}$ inch. Fig. 9,990 shows a lapped seam ready for burning. The face of the underside is shaved the width of the seam, and the over lead on the under side, as well as on the upper face, the width being a little less than the width of the seam for butt burning. The shaving is done with an ordinary shave hook and straight edge. To burn either of these seams, first regulate the gas and air cocks or the gas and oxygen cocks of the generator as the case may be, so as to obtain a "hard solid flame."

A gas furnace is very desirable for brazing. An air blast is necessary as in the forge but a comparatively small blower will suffice. The accompanying illustrations show the various methods of heating in brazing.

Lead Burning.—This process, sometimes erroneously called autogenous soldering, consists of *joining pieces of lead together by simply placing the edges to be joined close to, or overlapping each other, and then melting them so that they flow and intermingle with each other, forming one piece, and retaining the same condition of unison on solidifying.*

In some cases a strip of lead is melted at the same time as the edges; this makes a raised, and consequently a stronger seam. The process is useful only for joining lead to lead and would not answer so well for joining lead to copper or to brass.

In lead burning, a hydrogen flame is used in connection with a jet of air, the hydrogen being produced in a machine or generator.

For joining lead sheets together by burning, it is essential that the pieces touch or overlap each other when in the horizontal position, and overlap when in either slanting, upright, or overhead positions. It is not necessary to *soil* the sides of the seams, because the lead will flow only where it is directed by the flame jet. No fluxes are necessary.

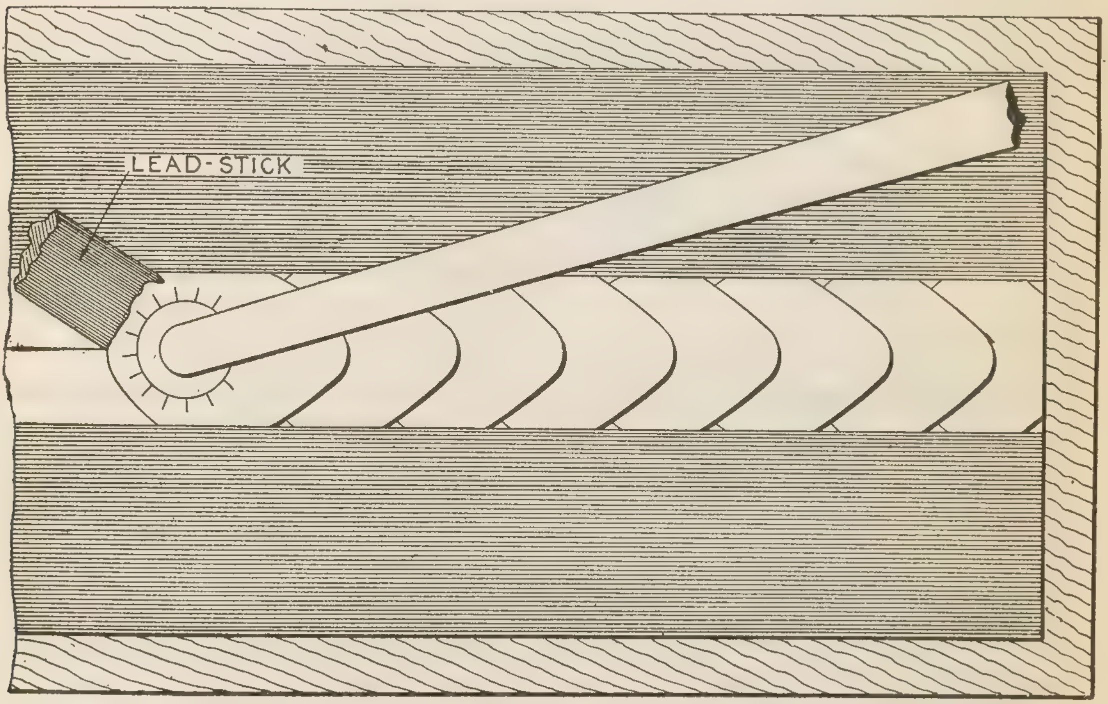


Fig. 9,991.—Process of burning a butt seam in two sheets of lead.

The details of preparation of butt and lap seams are shown in figs. 9,989 and 9,990.

To burn either of these seams, first regulate the gas and air cocks or

the gas and oxygen cocks of the generator as the case may be, so as to obtain a "hard solid flame."

For flat butt burning the end of a stick of lead should be held on the seam so as to be melted at the same time as the other lead, as shown in fig. 9,991.

During the process of burning, the sheet lead will be expanded when the heat is applied, and being a poor conductor, the heat is not distributed to the adjoining sides of the seam, hence the heated parts will rise up and leave hollow spaces underneath. When this happens, leaving places where the lead does not rest in the board, the lead melts more readily, with the result that a hole is made, through which the molten metal will flow. To prevent this, the lead should be held down with the end of the stick of feeding lead, which is held in the left hand.

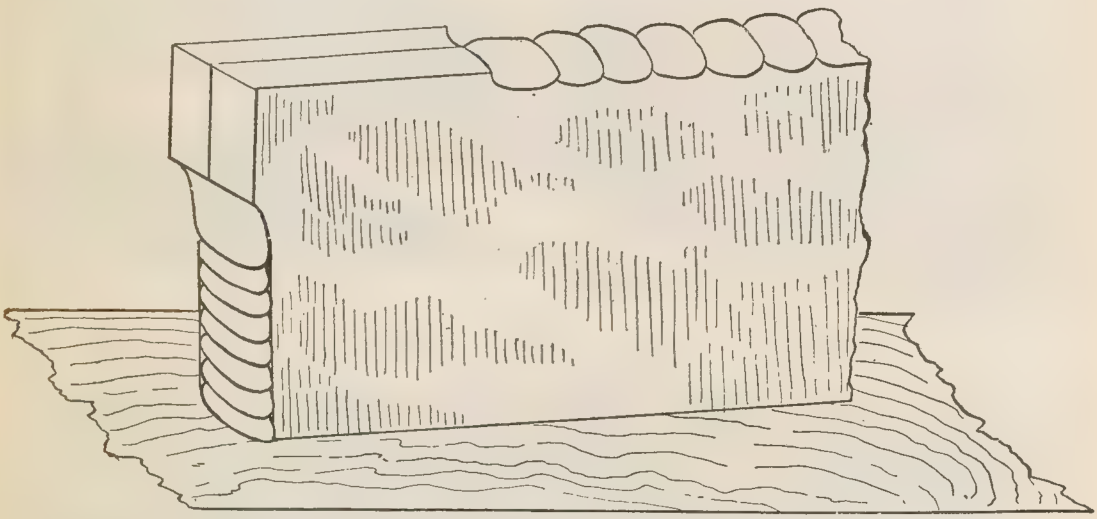


Fig. 9,992.—Edge burning. In this case no feed lead is necessary, but a slight jar has to be given to start the first bead on either the vertical or the horizontal seam.

Before beginning to burn the seam, a stick of lead should be held in the hand and the flame made to play upon it so as to ascertain the hottest part of the flame to apply to the seam.

If the flame tarnish or smoke the lead stick, more air or oxygen should be burned in, but if the lead turn to a silvery brightness, when the flame impinges, the heat will be right and the part of the flame to be used will be ascertained.

Now tack the two ends of the seam by melting little beads on them to hold the pieces in position.

The burning can now be started, beginning being made at the right hand end. The flame is lifted immediately when the metal begins to flow and reapplied at a distance of from ⅛ to ½ inch, according to the thickness of the lead being joined together, giving the appearance shown in fig. 9,991.

CHAPTER 153

Welding

The art of *forcing two pieces of metal into union by means of heat and pressure*, is known as ***welding.***

Until the introduction of electric welders, it has always been a difficult process, requiring considerable experience and skill of hand and eye. Not only must the temperature of the heated iron be properly judged for a successful weld, but the metal itself must be protected from the effect of the oxygen in the air.

Oxidation of Iron.—If a piece of iron be heated in contact with air, it will absorb oxygen from the air, thus forming a scale of oxide of iron on the surface. The hotter the iron, the more rapidly will the scale form.

Oxide of iron prevents welding because it lies between the two surfaces to be united and prevents their coming into contact.

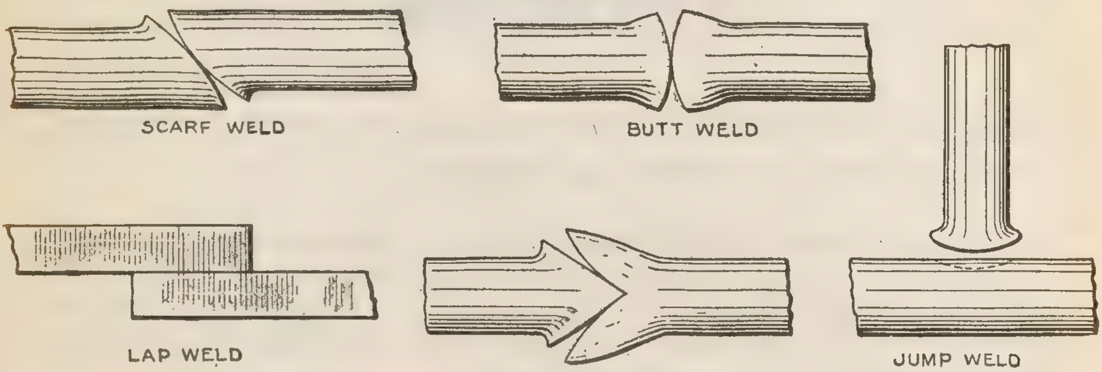
Methods of Preventing Oxidation.—There are two methods used in welding to prevent the formation of oxide of iron, and both methods are based upon some means of protecting the hot iron from the oxygen in the air.

Oxidation may be prevented by using: 1, a reducing fire, or, 2, a protective coating. A reducing fire is one in which all the oxygen is consumed in the combustion. In practice this is accomplished by having a closed thick bed of fire for the air to pass through before coming in contact with the iron and by maintaining a moderate biast.

A protective coating, called a *flux* is a substance containing no oxygen, which is applied to the heated metal, and which possesses certain qualities which prevent oxidation.

Fluxes.—The usual composition of fluxes for the various metals are as follows:

Cast Iron.—Equal parts of carbonate and bicarbonate of soda to which



FIGS. 9,993 to 9,997.—Various welds. Fig. 9,993, ***scarf weld.*** In this weld *the two pieces are chamfered*, that is beveled. If the iron be of uniform thickness it is first upset at the point where the weld is to be made to make it a little thicker, then it is scarfed. To scarf, the upset end is thinned down, generally with the peen of the hammer, drawing it out thin at the point and crowding the metal together at the stick. The faces to be welded are given a crown shape to facilitate squeezing out of the slag as the weld is closed. Fig. 9,994, ***butt weld.*** This is *an end to end weld*. Usually the two pieces are upset a little at first, and then ends welded together. They are hammered on end to bring them together, and as this tends to upset the pieces some more, they are drawn out to the required size after the weld has been made. In preparing the ends, the surfaces to be welded are made convex as in the scarf weld, in order to allow the slag to work out. Fig. 9,995, ***lap weld:*** a weld in which *the faces of the two pieces overlap*. When the faces are not crowned or rounded, care should be taken to begin hammering at the center and work outward to force out all the slag. Fig. 9,996, ***cleft or split weld:*** a *"tongue and groove" form of weld*. One of the pieces after upsetting on the end to gain width, is split in the center making a V shaped groove; the other piece is chamfered on both sides bringing it to a point to form a V tongue to fit the groove. In welding the two pieces they are "stuck" together by hammering on the end, and then on the sides of the groove piece to close the weld. The V groove should not have straight sides but slghtly rounded as shown so that the slag may be forced out in closing the weld. Fig. 9,997, ***jump weld.*** *A weld formed by bringing the ends of a bar together* and ***jumping them*** *upon the anvil, or with a heavy hammer.*

is added 10 to 15 per cent. of borax and 5 per cent. of precipitated silica. Ordinary table salt may also be used.

The flux should be used only when the metal does not run freely, and then only sparingly.

Too much causes the metal to harden so that it cannot be machined.

Steel.—Borax, boracic acid, sodium chloride (salt). It is used only when the metal will not run.

Mild Steel and Wrought Iron.—Same as for steel, used sparingly or not at all.

Copper, Brass, and Bronze.—Same as above. When used for brass make a paste with a little water.

Aluminum.—Flux consists of, 15% lithium chloride; 45% potassium; 30% sodium; 7% potassium fluoride; 3% bisulphate of potassium. Another flux for aluminum is plain borax.

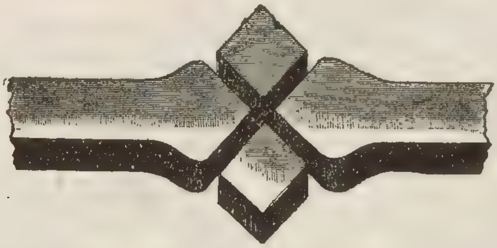


FIG. 9,998.—***Glut Weld.*** *A weld in which the ends of the two parts are tapered down, and the angles filled with wedges of iron,* the whole being welded together while checking the length with a trammel, excess material being subsequently cut away. This type of weld is generally used in repair work where it is necessary to maintain unchanged the length of the broken part.

Various Welds.—These may be classified according to the way the ends are formed prior to making the weld, as

1. Scarf weld;
2. Butt weld;
3. Lap weld;
4. Cleft or split weld;
5. Jump weld;
6. Glut weld.

In addition, there are two processes, known as: 1, fagoting, and 2, building up. Fagoting consists in assembling a quantity of iron junk such as old bolts, pieces of chain, turnings, and other scrap iron, and forging the mass into a billet or slab.

Building up is the process of making a multi-piece forging.

NOTE.—It will be noticed from the illustrations of the various welds that *the surfaces are in most cases* ***rounded or curved.*** This is done so that when the heated ends are brought together they will unite first in the center. Any slag or dirt which may have adhered to the heated surfaces *will then be forced out as the welding proceeds from the center outward.* When making a lap weld, the hammering should begin at the center in order to work all the slag out, as the faces in this case are not rounded.

Forge Fuels.—Several kinds of fuel, such as: charcoal, coal, coke, and gas are used for heating metal in welding. Perhaps bituminous coal is mostly used, though for general work coke is considered the best.

The most desirable grade of soft coal is that containing the least percentage of sulphur, because sulphur makes iron brittle while hot. With anthracite coal it is difficult to get the fire hot enough especially on a large forge. Fuels should not contain lead, sulphur, brass of bronze.

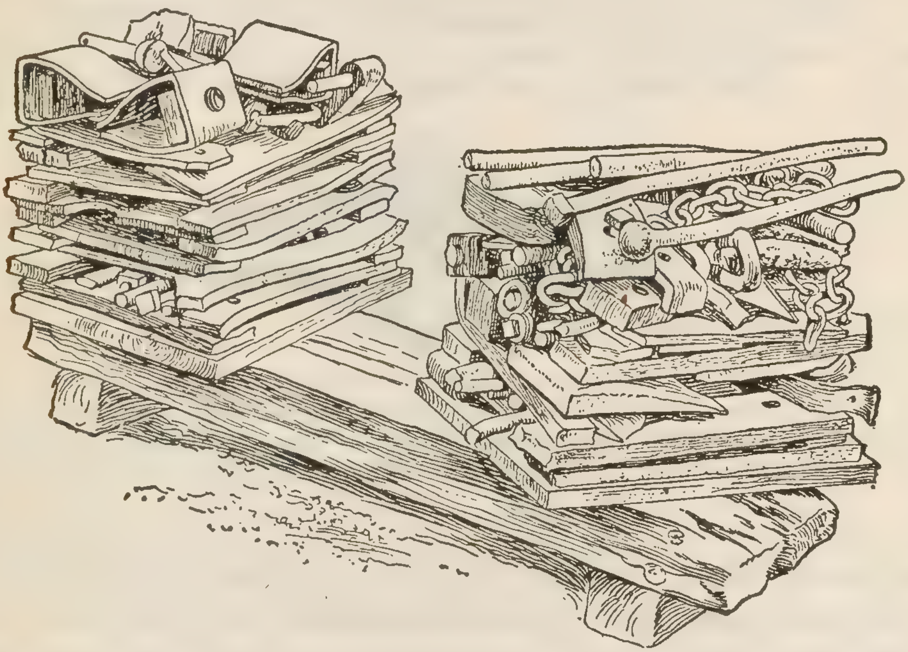


FIG. 9,999.—***Fagoting.***—The pile is started with a flat piece of iron, generally fagoted up of small pieces and the pieces of scrap iron piled on top of this, making a firm rectangular pile with large pieces around the outside and small pieces in the center, or the flat piece on the board may be omitted. It is then heated in a furnace and welded under a steam or a machine hammer.

Systems of Welding.—Welding is and has long been a matter of great practical importance, chiefly in the manufacture of iron and steel, and of the various tools, utensils and implements of those metals. Iron has the valuable property of continuing in a kind of pasty condition through quite a wide range of temperature, below its melting point, and this is a circumstance highly favorable to the process of welding. Most metals,

however, pass quickly, when sufficiently heated, from a solid to a liquid condition, and with such welding is more difficult.

The term welding is more generally used when the junction of the pieces is effected without the actual fusing point of the metal having been reached. Sheets of lead have sometimes been united together by fusing the metal with a blow pipe along the two edges in contact with each other, and this has been called autogenous soldering, or burning if the heating were done with a hot iron.

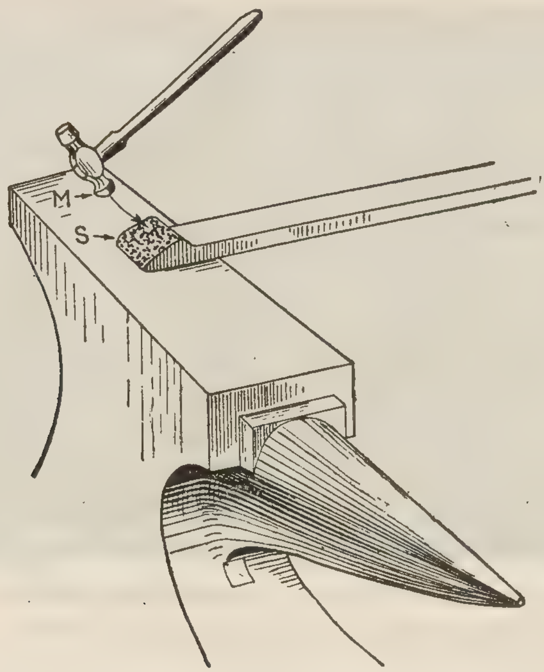


FIG. 10,000.—Making a scarf for a scarf weld. To do this, the upset end is thinned down, generally with the peen of the hammer, drawing it out thin at the point and crowding the metal together at the stock by drawing the hammer as shown at M. The faces to be welded should be rounded as shown at S, so that the pieces first come in contact at the center, in order to give the slag and impurities an opportunity to squeeze out as the weld is being closed.

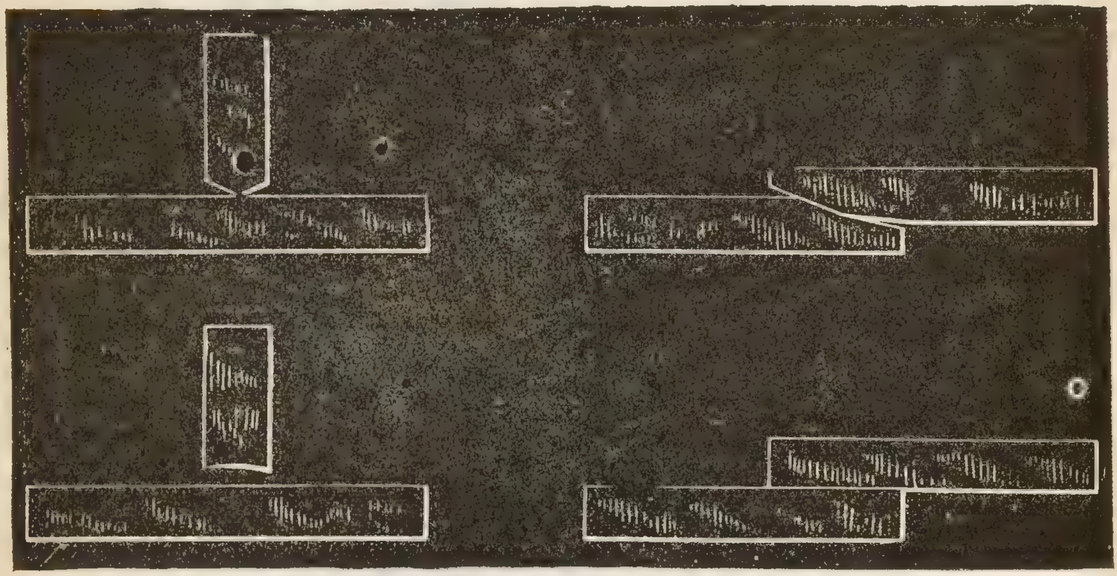
According to Percy, "the difference between welding and autogenous soldering is only one of degree. The term welding is also used in speaking of the uniting of articles not metallic. Most metals when in the form of powder can be consolidated or welded into a perfectly homogeneous mass by sufficient pressure, without the aid of heat. The same is true of various non-metallic substances, such as graphite, coal, and probably many others.

Welding Methods.—The various systems of welding may be classified; 1, With respect to the method of working as,

1. By hand;
2. By machine.

2. With respect to the treatment of the metal, as

1. By hammering;
2. By fusing (autogenous).



Figs. 10,001 and 10,002.—Correct shapes for jump and lap welds.
Figs. 10,003 and 10,004.—Incorrect shapes for jump and lap welds.

3. With respect to the method of heating, as

1. By forge fire;
2. By blow pipe;
3. By combustible mixture;
4. By ***electricity.***

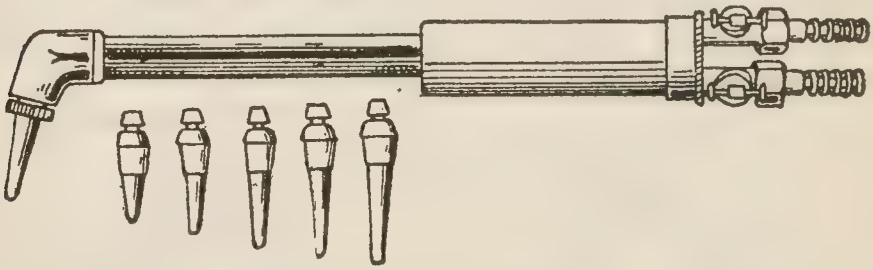
Blow Pipe Welding.—This method consists in *uniting the metal pieces by means of a blow pipe flame* of appropriate temperature with the addition of metal of the same composition, the joint thus obtained is called autogenous.

The blow pipe used is an instrument in which the flames are produced and projected on the metallic parts to be welded.

The flame produced by the blow pipe is of unusually high temperature.

First oxy-hydrogen was used, in the blow pipe, then oxy-acetylene, and later, oxygen and coal gas, and oxygen and benzol, etc.

The temperature of the oxy-hydrogen flame is approximately 4,000° Fahr., and the oxy-acetylene flame, 6,300°.



FIGS. 10,005 to 10,010.—Davis-Bournonville oxy-acetylene blow pipe, or "torch." Both gases being admitted to the mixing chamber at appreciable pressure, and at right angles to each other, the maximum of molecular contact of the two gases is secured. The working pressure of both gases is controlled by regulators on the tanks. The type of torch shown, the "positive mixture torch," is for light, medium or heavy welding.

In making an autogenous weld, the torch should be given a rotary motion, accompanied by a slight upward and forward movement with each rotation.

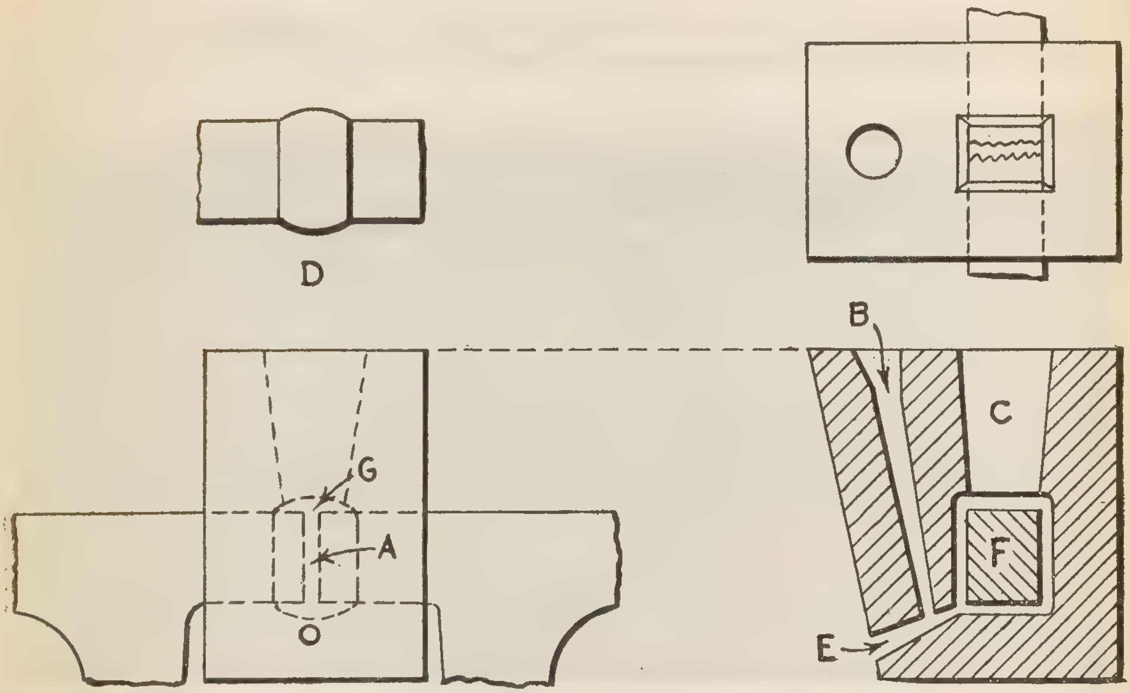
It looks easy, but isn't, and an inexperienced workman may produce a joint of perfect appearance, though defective under the surface.

This movement assists in blending the metal and reduces the liability of local overheating. It is desirable to keep the metal surrounding the spot operated upon to a fairly high temperature to prevent excessive conduction of heat away from this spot.

New metal should be added from a "weld rod" of suitable composition.

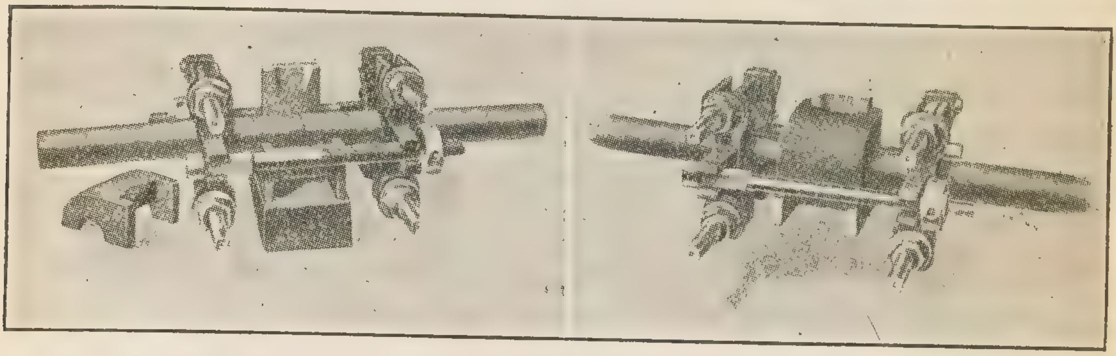
The surface should be thoroughly fused before adding metal from the welding rod, and the latter should be held close to, or in contact with the surface.

Before lighting the acetylene torch the regulator on the oxygen tank should be set to give the proper pressure. The average pressures used are, acetylene, 1 to 8 lbs.; oxygen, 2 to

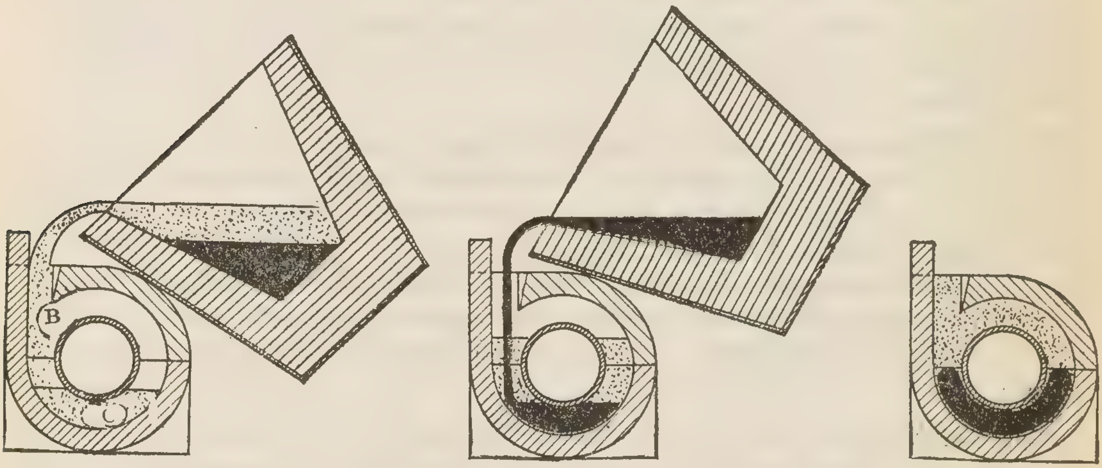


FIGS. 10,011 to 10,014.—Mould for thermit welding of locomotive frame that has been broken between the pedestals at A. The mould surrounding the broken part should be so arranged that the molten thermit will run through a gate to the lowest part of the mould and rise through into a large riser. In the mould here shown the thermit is poured through gate B, and rises into space C, after passing through and between the ends of frame F. The mould must allow for a reinforcing band or collar of thermit steel to be cast around the ends to be welded. Space G, for forming this collar, and the opening between the frame ends must be filled before ramming up the mould. Yellow wax is ordinarily used for this purpose. The shape of this band or collar should be as indicated by the view of the completed weld at D. The thickest part is directly over the fracture and the band overlaps the edges of the break at least one inch. Pattern for the riser, pouring and heating gates can be made of wood. The riser C, should be quite large because the steel that first enters the mould is chilled somewhat by coming into contact with the metal, even when pre-heated. This chilling effect is overcome by using enough thermit steel to force the chilled portion up into the riser and replacing it by metal which has practically the full temperature received during reaction. The mould must be of a refractory material owing to the intense heat. When the mould and box are filled and tamped, the wooden runner and riser patterns are withdrawn. The mould is then ready for pre-heating and the drying operation, which causes the wax matrix to melt and run out.

20 lbs., corresponding to a range of work from $\frac{1}{32}''$ to $1\frac{1}{2}''$ in thicknesses. For greater thicknesses two torches may be



FIGS. 10,015 and 10,016.—Thermit pipe clamps and mould. Fig. 10,015, pipes held in clamps. Mould partly assembled for thermit welding. Fig. 10,016, mould fully assembled ready for weld.



FIGS. 10,017 to 10.019.—Thermit pipe welding operation. Fig. 10,017, slag flowing into mould and coating inside of pipe and inside of mould. Fig. 10,018, slag in mould and steel following, displacing slag in bottom part. Fig. 10.019, both slag and steel in mould but steel separated from pipe and mould by film of slag. In making a butt to butt thermit pipe weld, the pipe ends are first faced very accurately and are then held tightly together by means of clamps. A cast iron mould is then placed around the pipe ends and the proper amount of thermit ignited in a small flat bottom crucible or ladle. As soon as the thermit reaction is over (about ½ minute), the contents of the crucible are poured into the cast iron mould. The liquid aluminia or slag which floats on top of the molten mass in the crucible, naturally goes into the mould first and covers the inside of the mould and the outside of the pipes with a protective coating which prevents the superheated liquid steel, which flows in afterwards, coming in contact with either. The heat of the entire mass, however, serves to bring the pipe ends up to a welding temperature at which time they are squeezed together by means of the clamps and a butt weld effected. The entire thermit mass can then be knocked away from the pipes and nothing will stick to either the pipe or the mould. A slight upset will be observed on the outside of the welded pipe but the inside diameter is in no way affected.

used, or preheating of the parts resorted to. The acetylene is lighted first, the regulator being adjusted to the working pressure so that there is a fairly strong flame. The full working pressure of the oxygen is then turned on, after which the pressure is slightly varied by regulation until the two cores which appear in the inner flame at first are merged into one smaller core giving the proper welding flame.

Thermit Welding.—This process consists in *pouring superheated thermit steel around the parts to be united.*

This thermit steel is produced by the chemical reaction between finely divided aluminum and iron oxide when ignited. This reaction when started in one spot continues throughout the entire mass, without the supply of heat or power from outside and produces superheated liquid steel and superheated liquid slag (aluminum oxide) at a temperature of approximately 5,400° Fahr.

From 30 seconds to one minute is sufficient time to bring into reaction almost any amount of thermit. The thermit steel when poured into a mould surrounding the ends of the sections to be united dissolves the metal with which it comes in contact and amalgamates with it to form a single homogeneous mass when cooled. It is necessary, however, in all cases to preheat the sections before pouring the thermit steel, as otherwise they would exert a chilling effect on the incoming metal and prevent successful fusion.

The essential steps of the operation, therefore, are to clean the sections, and remove enough metal to allow for a free flow of thermit steel, then surround them with a mould, preheat by means of a gasoline torch, ignite the thermit in the crucible suspended over the pouring gate of the mould, and then pour the thermit steel.

The average composition of thermit steel is, carbon .05 to .1; manganese, .08 to .1; silicon, .09 to .2; sulphur, .03 to .04; phosphorus, .04 to .05; aluminum, .07 to .18.

Electric Welding.—By the electric process, all metals and alloys can be welded, and dissimilar metals and alloys united, because the temperature can be maintained or increased while

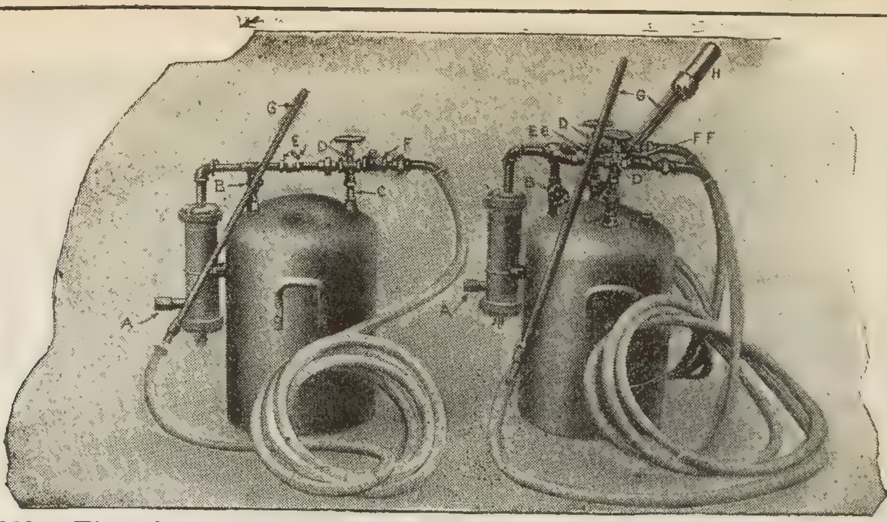


FIG. 10,020.—Thermit preheater. ***Directions for operating:*** The preheater is connected with compressed air supply at A. The air pressure should be at least 15 lbs. per sq. in., but 50 lbs. or more is recommended. Valve B allows the compressed air to flow into the top of the gasoline tank and places the gasoline contained therein under pressure, driving it up through the pipe C into the needle valve D, which regulates the amount of gasoline to be mixed with the compressed air which flows across by pass E around the needle valve and through the check valve F into the hose and so on to the burner. The gasoline and air become mixed together at the needle valve and also through the passage from D, to the burner G. To regulate the torch, use valves D and E, which control the gasoline and the flow of compressed air respectively. In starting the torch, place it in position in front of the heating gate of the mould but about 1 inch away from the mould. Place some oily waste or a flame of some kind at the end of the burner pipe, sufficient to keep the burner lighted until it is satisfactorily regulated. Open the air valve B, wide and then open the air valve E, from one-half to one full turn according to the air pressure used, and then the gasoline valve D about one-half to three-quarter of a turn, this amount also depending upon the air pressure. The burner will take a few minutes to get properly started because the hose and burner pipe are cold, tending to liquify the gasoline vapor. Gradually as the burner pipe becomes hot the flame will become steady. The burner is lighted more easily if at first an excess of gasoline be used, as the flame becomes more steady this excess should be cut down. Unless the mould be intricate so that a strong flame would tend to break it, the air should be increased after the flame is well started, and then the gasoline increased correspondingly. Too much air will tend to extinguish the flame. Too much gasoline will result in liquid gasoline dripping from the end of the burner pipe. If wax has been used as a pattern it should of course have been provided with a vent connecting the heating gate with the riser. Shortly after the burner is started this wax will melt out, running out of the heating gate and coming from the riser in the form of a heavy white vapor. This heavy white vapor should be ignited at the top of the riser and pouring gate to eliminate the fumes from the room and the burner removed from time to time to allow the liquid wax to run out. If the mixture be right there should be no flame at the end of the burner pipe when it is taken away from the mould. If there should be a flame at the burner pipe the air valve and probably the gasoline valve should be opened wider. After the wax is burned out small sheet iron plates should be placed over the riser and over the pouring gates to hold the heat in the mould. If one part heat more rapidly than another, the heat should be regulated by means of these plates, and by shifting the burner pipe in, out and sideways. Toward the end of the preheating, place the burner in the riser and in the pouring gate so that any loose sand may be blown out through the heating gate. In stopping the burner turn off the gasoline valves D and B completely, but leave the air valve E turned on or perhaps open it wider to blow all gasoline vapor out of the burner pipe. Drain the water out of the water separator from time to time through the pet cock at the bottom. All the above applies equally well to kerosene and to gasoline.

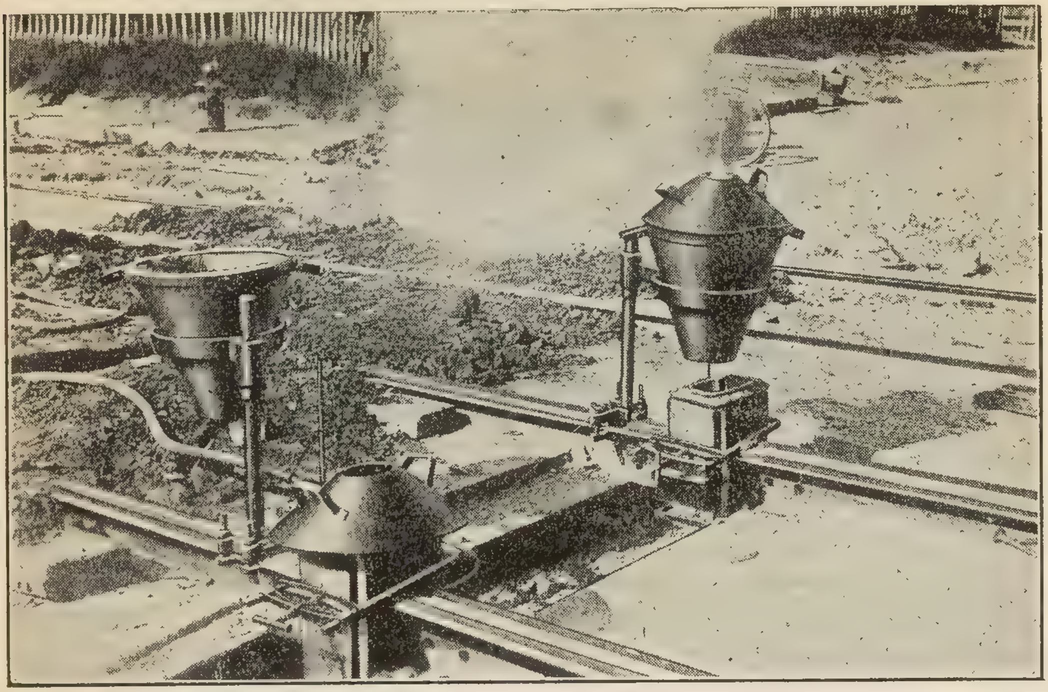


FIG. 10,021.—Open mould and crucible in position for making Clark thermit rail joint. In its original form the Clark joint consisted of a combination of splice bar and thermit steel, it being Mr. Clark's opinion that the head of the rail could be supported by using plates that would come under the ball of the rail. Furthermore, in order to hold the rail rigid, he considered it important that there should be no play in the bolts, so the holes in the plates and rails were drilled round and machine bolts used after reaming for a drive fit. In order to keep the bolts and plates from working loose, and to afford bonding between the rails, a thermit steel shoe was cast around the base. ***In practice,*** the rails and splice bars are drilled with holes 1/16 of an inch less in diameter than the bolt to be used. The splice bar is then applied in the ordinary way and held in place by a couple of temporary bolts, a drift pin being driven into one hole each side of the joint to keep the rails in position. The remaining holes are then reamed with straight end cutting reamers, after which the machined bolts are driven and tightened up in the usual manner. After pre-heating the rail ends, the thermit steel is run into an open mould surrounding the lower part of the rails. In the latest type of Clark joint, rivets are substituted for the machined bolts, the riveting being accomplished by a pneumatic riveter mounted on a flat car manipulated by means of a small derrick. A modification of the Clark joint has recently been adopted by the United Railways & Electric Co., of Baltimore. The object of the modification was to obtain a larger weld of the base, and in order to do this, the thermit steel was poured into an enclosed mould box instead of into an open mould and the rail ends were preheated to a red heat with the moulds in place before the thermit charge was ignited. Furthermore the design of the fish plates is somewhat changed, being of special design, one inch thick and 32 inches long and so formed as to fit snugly the carbon of the head and base of the rail. At the same time, they provide a minimum amount of space between the web of the rail and the vertical sides of the fish plates. The channel bars and rails are of the same kind of steel (high carbon) and both are punched at the mill with ten 1/16 inch holes, spaced 3 inch centers and beginning 2 inches from the end of the rail. The joint has been applied thus far exclusively to 7 inch girder groove rail weighing 103 pounds per yard. These 7 inch girders sections are undercut by the manufacturers 1/16 inch so as to provide a space of 1/8 inch at the base when the rail ends are butted. This procedure more effectively enables the thermit steel to weld the rail and fish plates into a solid mass at the joints.

the weld is being made. An ordinary forge fire, involving as it does, the possible inclusion of dirt, irregular heating, difficulty of inspection and control of heat, cannot comply with the best conditions of welding which are:

1. The impossibility of introducing foreign matter into the weld.
2. Uniform heating of the area to be welded.
3. Continuous inspection during the process of heating.
4. Early and complete regulation of the heat.

FIGS. 10,022 and 10,023.—C and C electric arc welding apparatus. Fig. 10,022, operator with one type of head shield and combination electrode holder for both metallic and graphite electrodes. Fig. 10,023, graphite electrode holder and hand shield.

All systems of electric welding are based upon the principle of causing a current of electricity to pass through a high resistance, thereby generating heat. There are, however, important differences in the manner in which the heat so generated is applied to the welding of metals.

The amount of work done in a given time to force a current through a resistance is

$$\text{watts} = \text{amperes} \times \text{volts}$$

and since by Ohm's law, volts=amperes×ohms,

$$\text{watts}=\text{amperes}^2\times\text{ohms}$$

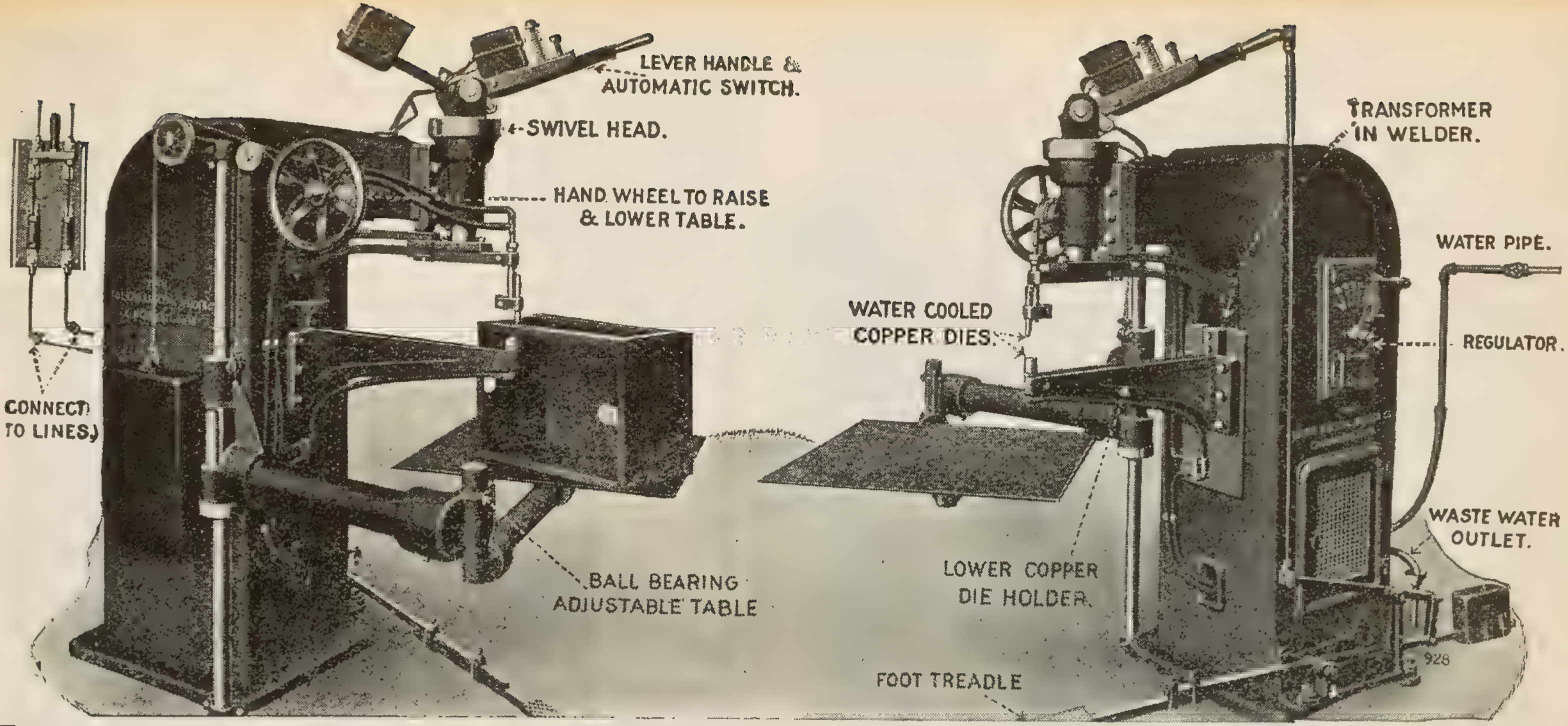
or expressed in the usual symbols

$$W=I^2R$$

which shows that in order to obtain a considerable heating effect by means of electricity, it is only necessary to send a large current through a conductor of high resistance.

FIG. 10,024.—Operator using C and C electric arc welding metallic electrode. The electrode itself is melted and supplies the extra metal necessary for welding or building up.

NOTE.—***Prof. Elihu Thomson,*** in 1877, at the ***Franklin Institute,*** Phialdelphia, while experimenting with induction coils caused the discharge of a Leyden battery to pass through the fine wire coil, which thus became a high pressure primary, while at the same time the ends of the coarse wire coil were brought into light contact. He noticed that these ends were partially welded together, so that it took some little force to separate them. His invention of electric welding was accordingly the outgrowth of this early observation. In 1881, when it was impossible to obtain copper wire in long lengths for dynamo fields, which necessitated the making of frequent joints in a heavy coil, Prof. Thomson discussed the possibility of electrically welding these wires, and in 1885 he constructed a practical electric welding machine for welding small sections of wire and tools. The various methods of electrical welding are here briefly described.

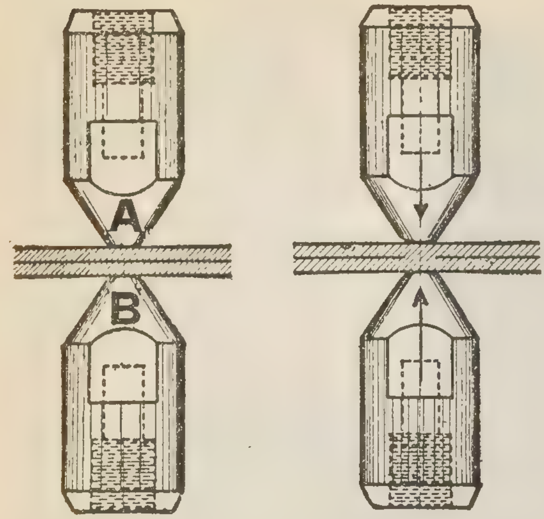


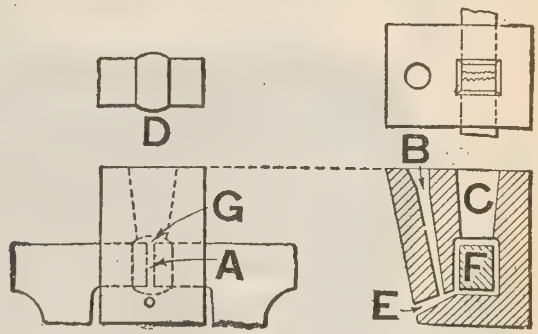
FIGS. 10,025 and 10,026.—Views of Toledo spot welder showing parts. Two wires run to the machine from the source of supply. Connect these to the wires from the welder marked "line." A half-inch water pipe connected to the city water is ample for cooling.

SIZE WIRE TO USE WHEN WELDER IS NOT MORE THAN 150 FEET FROM SOURCE OF POWER

Kw. capacity	Kva. capacity	110 Volt			220 Volt			440 Volt			Standard dynamo to operate welder	Motor generator set to operate welder	
		Wire No.	Fuses amp.	Switch amp.	Wire No.	Fuses amp.	Switch amp.	Wire No.	Fuses amp.	Switch amp.		H.P. of D. C. motor	A.C. dynamo
5	7.5	6	60	60	8	30	30	10	15	15	7.5 K.V.A.	7.5	7.5 K.V.A.
10	15	2	150	150	6	75	75	8	40	50	15 "	15	15 "
15	20	0	200	200	4	100	100	6	50	50	20 "	20	20 "
20	30	000	300	300	2	150	150	6	75	75	30 "	30	30 "
35	50	...	...	...	00	250	250	2	125	125	50 "	50	50 "

The above is safe carrying capacity for intermittent service, where current is never on more than two to three seconds.





FIGS. 10,027 and 10,028.—***Spot welding.*** This is *the process of joining or fusing together electrically two or more metal sheets or parts without any preparation of stock.* ***In welding,*** two electrodes, or welding points, A and B, fig. 10,027, are brought to bear on the plates where it is desired to make the weld and a heavy current at a low electrical pressure is passed through the electrodes. The metal plates, as they are much poorer conductors of electricity, offer so great a resistance to the flow of current that they heat to a molten state, and then, by applying pressure on the electrodes, the metals are forced together and the weld is made, as shown in fig. 10,028.

FIGS. 10,029 and 10,030.—Mould for thermit welding of locomotive frame that has been broken between the pedestals at A. The mould surrounding the broken part should be so arranged that the molten thermit will run through a gate to the lowest part of the mould and rise through into a large riser. In the mould here shown, the thermit is poured through gate B, and rises into space C, after passing through and between the ends of frame F.

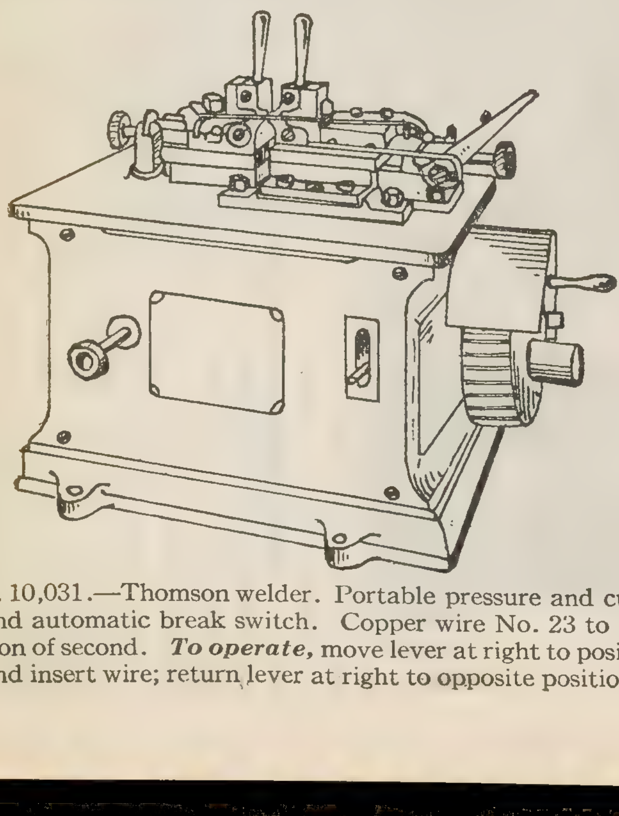


FIG. 10,031.—Thomson welder. Portable pressure and cut out, mercury slide, with regulator and automatic break switch. Copper wire No. 23 to No. 15. Power 1.5 *kw.* Time, fraction of second. ***To operate,*** move lever at right to position shown; hold back levers at center and insert wire; return lever at right to opposite position; press button and the weld is made.

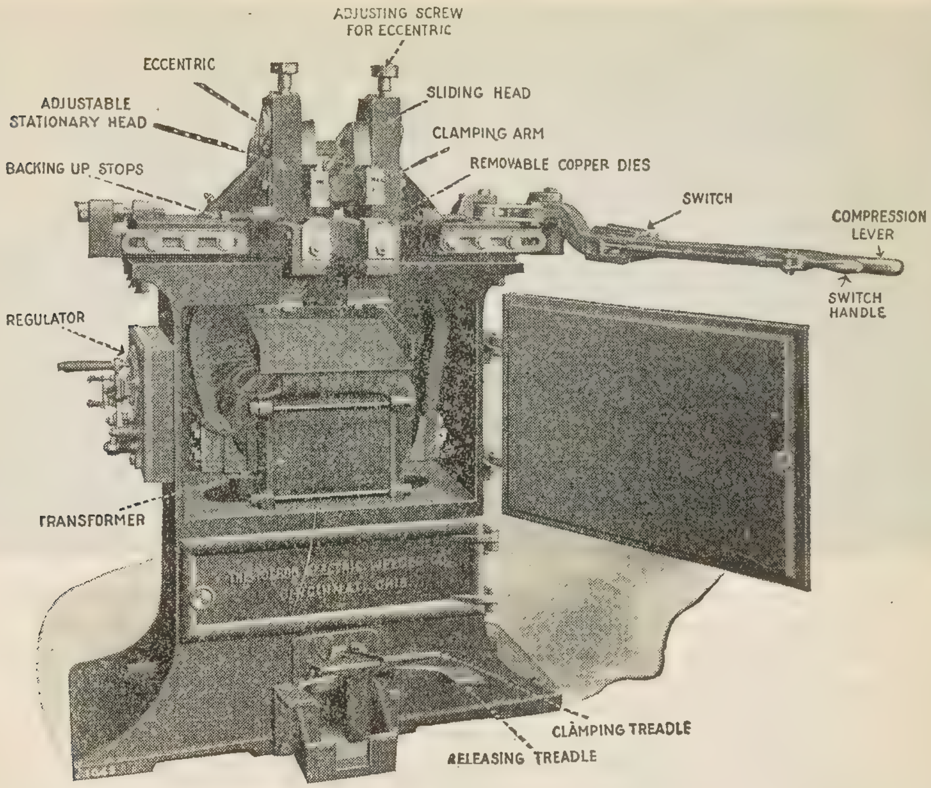
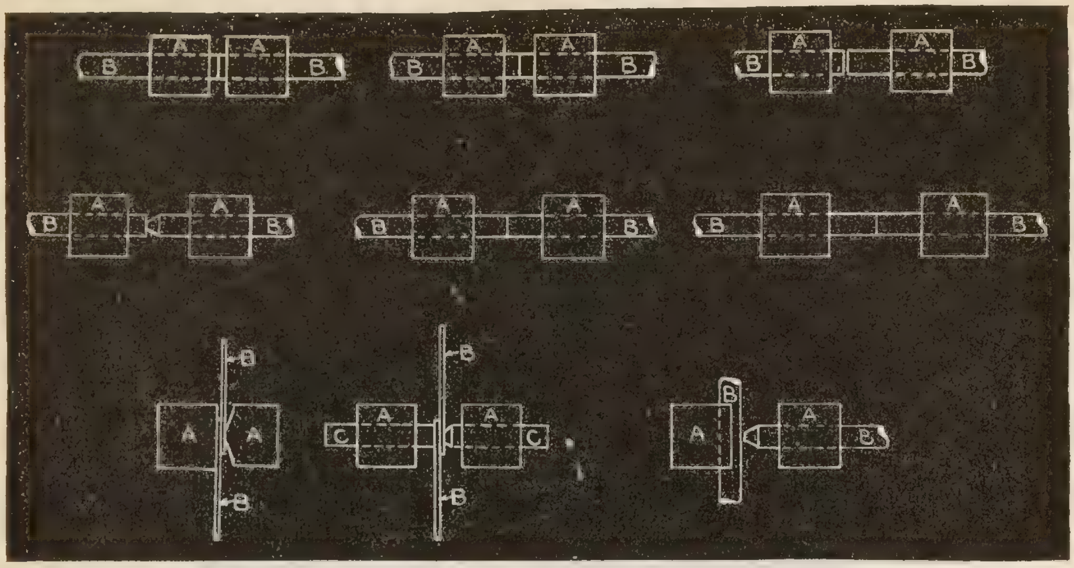


FIG. 10,032.—Toledo butt welder; view showing different parts. There are no auxiliary devices required when installing a welder, except the switch, fuses and water supply. Two wires run to the machine from the source of supply. Connect these to the wires from the welder marked "line." The switch to cut off the current when the machine is not in use and the fuses are usually mounted on the wall. A half-inch water pipe connected to the city water mains will afford an ample supply of water under all conditions. ***Instructions for operating:*** 1. Set the welder on either a wood or cement foundation and fasten down by lag screws or bolts. If set on wood foundation, the machine should be grounded by connecting a small copper wire from frame of machine to a water or gas pipe. 2. The wiring to the machine should be arranged with fuses and a double pole, single throw switch. 3. The transformer furnished with the machine is located in the base and is used to transform the current from the source of supply (either a dynamo or transformer) to the three to five volts used in the welding operation. The primary coils are connected to the double pole switch at the side of the machine. 4. Rubber tubing is furnished to connect the machine to city water supply and through the dies to the sewer. A globe valve should be inserted ahead of the welder to regulate the flow of water; just enough to keep the dies from becoming excessively heated. The amount of water required for this purpose is small and a ½ inch feed pipe to the welder will be ample. 5. After connecting the machine and water connections, the machine is ready to operate. Set the regulator handle to the extreme left hand side or No. 1, and the double pole, double throw switch to the left. Place two pieces to be welded in the copper dies, which are set from ¼ in. to 1 in. apart, according to the size stock to be welded. Let the ends of the stock touch each other; then turn on the current by means of the switch. If the stock do not heat rapidly enough, turn regulator handle to the right, or No. 2; if not enough heat be obtained at this point, keep on until point No. 5 is reached. If enough heat be not obtained, throw the double pole switch to the right and the lever handle to No. 1. The maximum current is obtained when the regulator is at the right, or at point No. 5, with the switch in the right hand position. A little experimenting



FIGS. 10,033 to 10,041.—General hints on electric welding. ***Cast iron*** cannot be commercially welded, as it is high in carbon and silicon, and passes suddenly from a crystalline to a fluid condition when brought up to the welding temperature. ***Iron or steel.*** It is necessary to keep the temperature below the melting point to avoid injury to the metal, and consequently considerable pressure is required to make the weld. The stock should be placed in the dies as shown in fig. 10,033 for a flash weld, and as shown in fig. 10,034 for an upset weld. A representing the dies, and B, the stock to be welded. ***High carbon steel*** can be welded, but must be annealed after welding to overcome the strains set up by the heat being applied locally at one place. Good commercial results are hard to obtain when the carbon runs as high as point 75 or above, and can only be done by an experienced operator. When below point 25, the operator can always be sure of making a good weld. To weld high carbon steel to low carbon steel, the stock should be clamped in the dies as shown in fig. 10,035, with the low carbon stock extending considerably further out from the dies than the high carbon stock. ***Nickel steel.*** This welds readily, and a small percentage of nickel materially increases the tensile strength of the metal. ***Iron to copper.*** These metals can be welded to each other, but it will be found necessary to reduce the cross section of the copper as shown in fig. 10,036. ***Copper and brass.*** When welding copper and brass the pressure must be less than when welding iron. The metal is allowed to actually fuse or melt at the juncture, and the pressure should only be sufficient to force out the burnt metal. This burnt portion being forced out, accounts for the good results obtained in welding these metals. The current must be cut off the instant the ends of the metal begin to soften. This is done by using an automatic switch which opens at any predetermined point. The sliding head is actuated by either spring or weight to force the heads together as soon as the metal softens, and this automatically operates the switch. As copper and brass are good conductors of the electric

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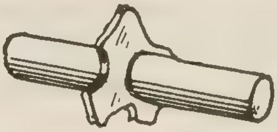
FIG. 10,032.—*Text continued.*

will give the correct heat necessary for getting the best results. Copper, brass, tool steel and all other metals that are deteriorated by high temperatures must be heated quickly and pressed together with sufficient force to push out all the burnt metal from the weld. On flash or upset welding of iron or steel, not more than once the diameter of stock is taken up in the weld. For example, in welding two pieces of ½ in. round stock, not more than ¼ in. of each piece is taken up by the weld, or a total of ½ in.

Thomson Process.—In this method a current of electricity heats the abutting ends of the two objects which are to be welded, these being pressed together by mechanical force, and so arranged with the electric current that there is great and rapid accumulation of heat at the joint, in consequence of the greater relative conductivity of the rest of the circuit.

Zerner or Electric Blow Pipe Process.—In this method *an electric arc is drawn between two carbon electrodes*. This arc is then caused to impinge upon the metal surfaces to be welded by means of an electromagnet. The arc is pointed to concentrate the heat, and the metal is fused around its point of contact with the arc.

This method is applicable to a rather limited range of small work, such as welding small steel and brass castings, plates, tubes, tanks, etc.



FIGS. 10,042 and 10,043.—Flash weld, and upset weld. ***A flash weld*** is generally used on stock that is wide and thin; where it is rectangular in shape, and where it is not possible to have the welding faces cut square and true. ***An upset weld*** is used in all cases where the weld is to be hammered, using the heat generated in the welding. Also for small rods or rings where it is not necessary to have a uniform thickness of stock. On brass or copper a flash weld is made. Three times the diameter of stock between the dies should be allowed on brass and four times on copper, but only once the diameter of stock is actually taken up in the weld.

FIGS. 10,033 to 10,041.—*Text continued.*

current, a larger volume of current at lower secondary voltage is used and the sliding heads are arranged to move with the least possible friction. The dies should be set apart approximately three times the diameter of the stock for brass and four for copper. See figs. 10,037 and 10,038. A, represents the dies, and B, the stock to be welded. The welds when properly made will stand the strain of the rolling or drawing process to reduce them to a smaller size. ***Spot welding.*** To weld two pieces of sheet steel at one small place or spot is called spot welding. For convenience of handling the stock this is usually done in a machine with vertical clamping dies. Where the size and shape of the pieces to be welded will admit, the work can be done in a butt welder equally as well. In this case one of the dies is slightly pointed and the stock welded between the dies as shown in fig. 10,039. Another way is shown by fig. 10,040, where two pieces of copper rod C, one of them slightly pointed, are clamped in the dies A. If galvanized iron is to be welded it will be found necessary to use two pointed dies instead of one flat and one pointed. ***Jump welding.*** This is for light stock only and the best results are obtained by slightly pointing one of the pieces as shown in fig. 10,041. The other piece is held with a portion extending outside the die, then bring them together, turn on the current and weld quickly.

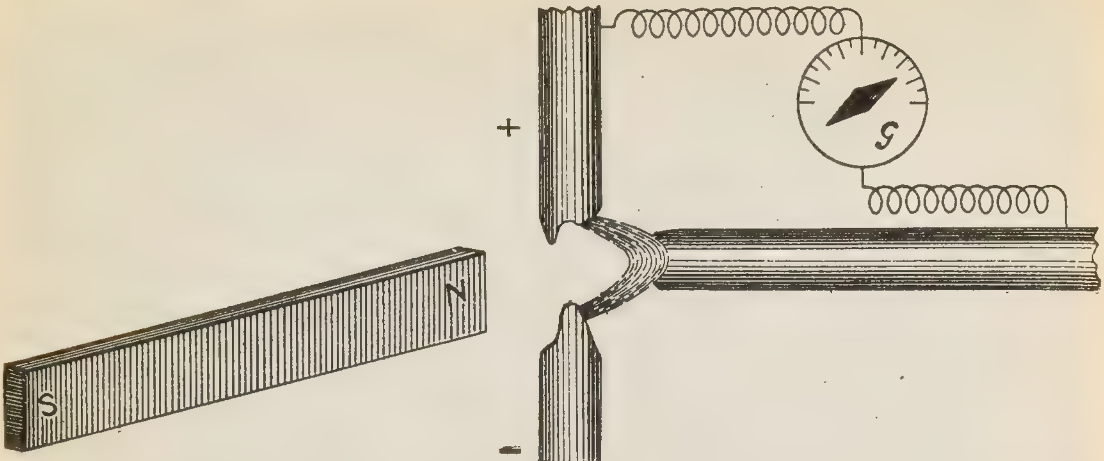


FIG. 10,044.—Electric blow pipe. ***It usually consists of*** two carbon rods, to each of which one pole of the electric circuit is connected, and an electromagnet energized by a shunt current is suspended over the arc. When the current is turned on a strong magnetic field is formed which produces a blow lamp effect on the arc, and by placing the article to be welded or brazed at varying distances from the flame, the heat can be regulated.

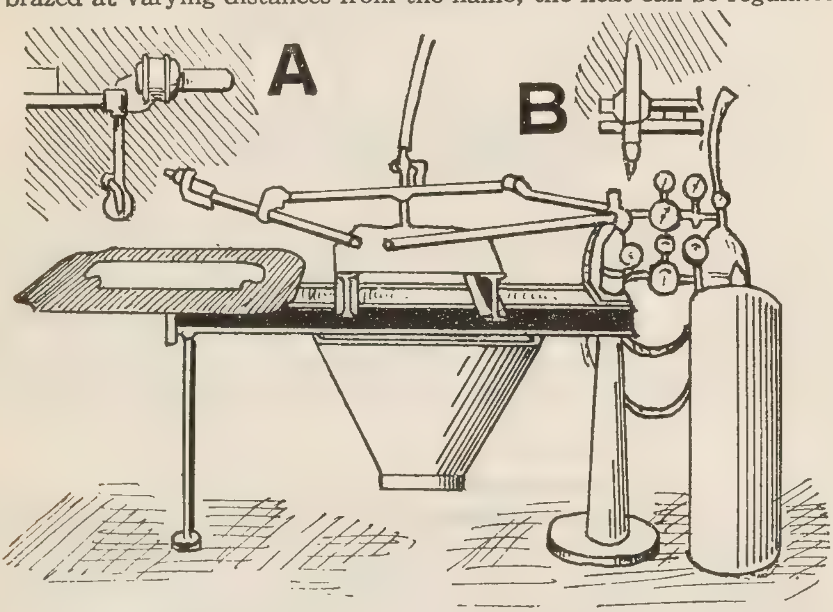
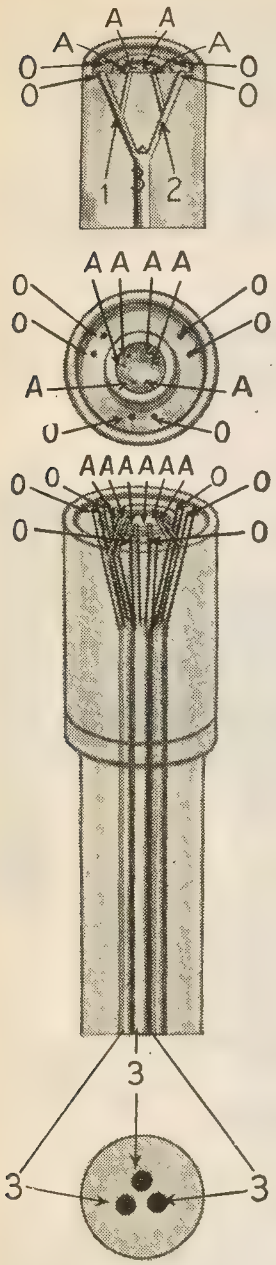


FIG. 10,045.—Davis-Bournonville oxygraph. At ***A***, is shown a motor rheostat and tracing device; at ***B***, the cutting torch. The oxygraph is seen below. This machine will cut steel up to six inches in thickness, at the rate of three to twelve inches per minute, a larger size cutting up to 18″ in thickness, and another modification, for circle or straight line cutting only, taking in armor plate up to 24″ thick. It has an electrically propelled rolling tracer, which is guided along the lines of a drawing, and the cutting flame will make an exact reproduction in one machine of one-half the dimensions, in another of the exact size of drawing. Steel can be cleanly and smoothly cut at short angles and of any irregular shape. The machine is desirable for die makers, blanking out connecting rods, crank shafts, etc. The motor can be connected to a lighting circuit or to a battery. The automatic uninterrupted feed adapts the machine to quantity work, and to all work where accuracy, as well as smoothness of cutting surfaces, or roughing out close to he required finished surface are essential.



Bernados Process.—*The metal to be welded is connected to one pole of an electric circuit.* When iron or steel is being welded, for which a high temperature is needed, the metal is made the positive and the carbon the negative. In the case of lead, or any metal requiring a comparatively low temperature, this polarity is reversed.

This process is especially adapted to the filling up of blow holes, cracks, etc., in steel castings.

Slavianoff or Modified Bernados Process.—In this method, *an electrode which is of the same material as the metal to be welded is used instead of a carbon electrode.* This change is made so as to prevent the hard welds which sometimes result with the Bernardos or Zerner processes, owing, principally, to the transfer of carbon from the electrode to the weld. A direct current of about 130 amperes and 24 to 26 volts across the arc is adapted for this process.

Hoho and Lagrange Process.—The apparatus used usually consists of a lead lined wooden tank, filled with an electrolyte of any conducting liquid solution, either alkaline or acid.

The positive pole of a dynamo, giving usually about 200 volts, is connected directly to the inner leaden sheath. The bar of steel or other metal to be heated, is connected to the negative pole and plunged into the bath. Directly the bar touches the liquid, electrolysis is set up and the water splits up into its component parts, the oxygen going to the leaden sheath

FIGS. 10,046 to 10,049.—Burco oxy-acetylene multiple mixer. ***It consists*** of three separate units, in each of which the gases employed are blended three times. ***In operation,*** oxygen is brought into the mixing chamber through ports O, acetylene through the ports A. One mixture of the two gases is effected at 1, another at 2, and then these two mixtures are blended at 3. Since there are three such mixing units, it is apparent that nine different mixings of the gases take place. While the gases are passing from the Burco multiple mixer to the tip, they are again mixed for the tenth time. The gases are mixed for the eleventh time in the tip through the expansion and contraction, and then passed out of the tip orifice to the flame.

and the hydrogen clinging to the metal, forming a complete gaseous envelope around it, and thus preventing the metal actually touching the solution. Here again, a high resistance to the flow of current is offered by the hydrogen sheath, and the electric energy is transformed into heat. It is difficult with this process to control the temperature.

A modification of the system consists in replacing the liquid by powdered carbon or charcoal, the article to be heated forming one pole, and the carbon,

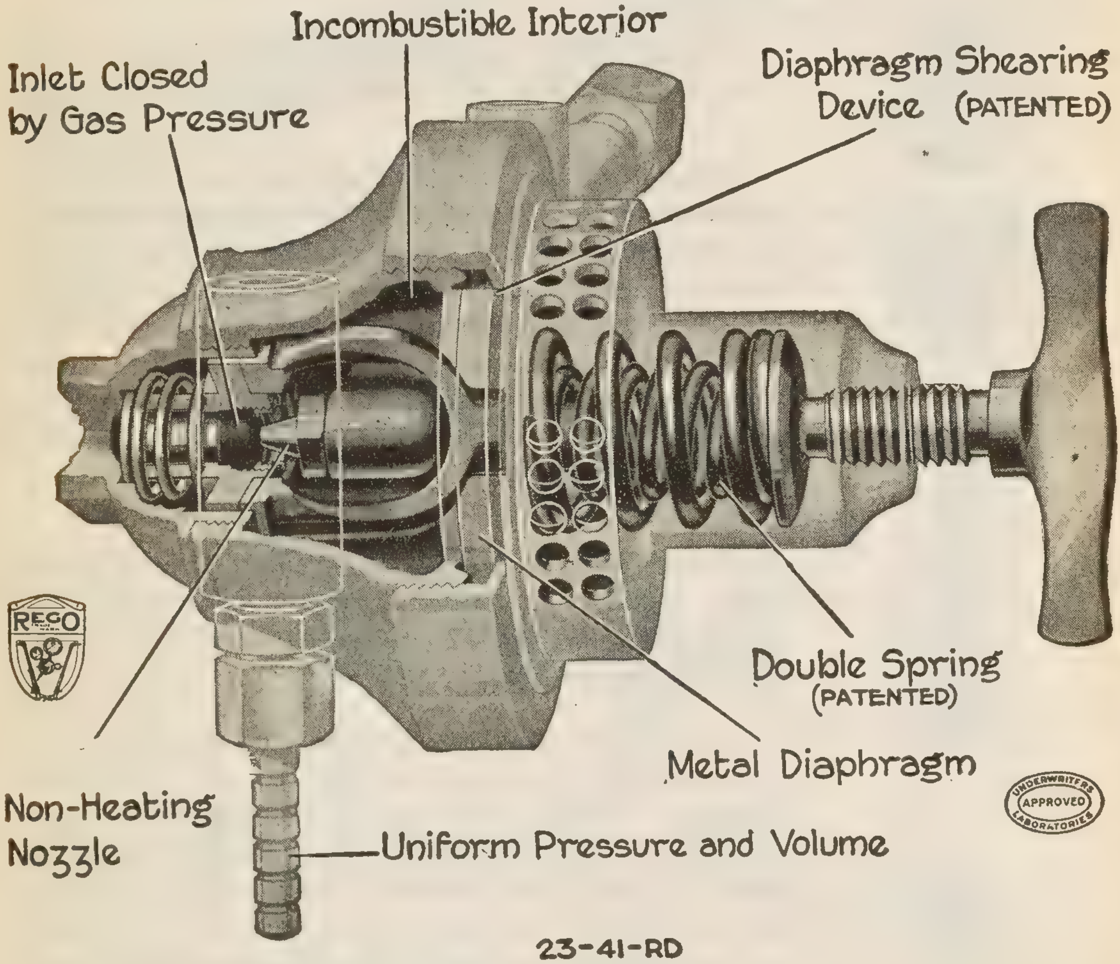


FIG. 10,050.—Rego pressure regulator. The diaphragm shearing device prevents the disastrous bursting of the diaphragm and bonnet in the event of accidental excess pressure in the body. This condition of excess pressure is not theoretical. It is liable to happen if the tank fall over or the torch back fire. A bonnet with vent holes in it, while of some value, is not sufficient. The diaphragm must also be relieved of the sudden tremendous pressure. The seat and nozzle of the regulator are brought together by the positive action of the gas pressure. The closing movement is not controlled by springs. Pressure of gas against the interior of the diaphragm pulls the yoke and seat tight against the inlet nozzle. The pressure of the nozzle against the seat increases in the same proportion as the pressure increases in the body of the regulator, the more pressure the tighter the seat.

the other pole. When the article touches, or is inserted in the powdered carbon, the resistance of the latter and its poor contact with the metal generate heat which is conducted to the object.

Oxy-Acetylene Flame Propagation.—Flame welding has been variously known by many different names as fusion welding,

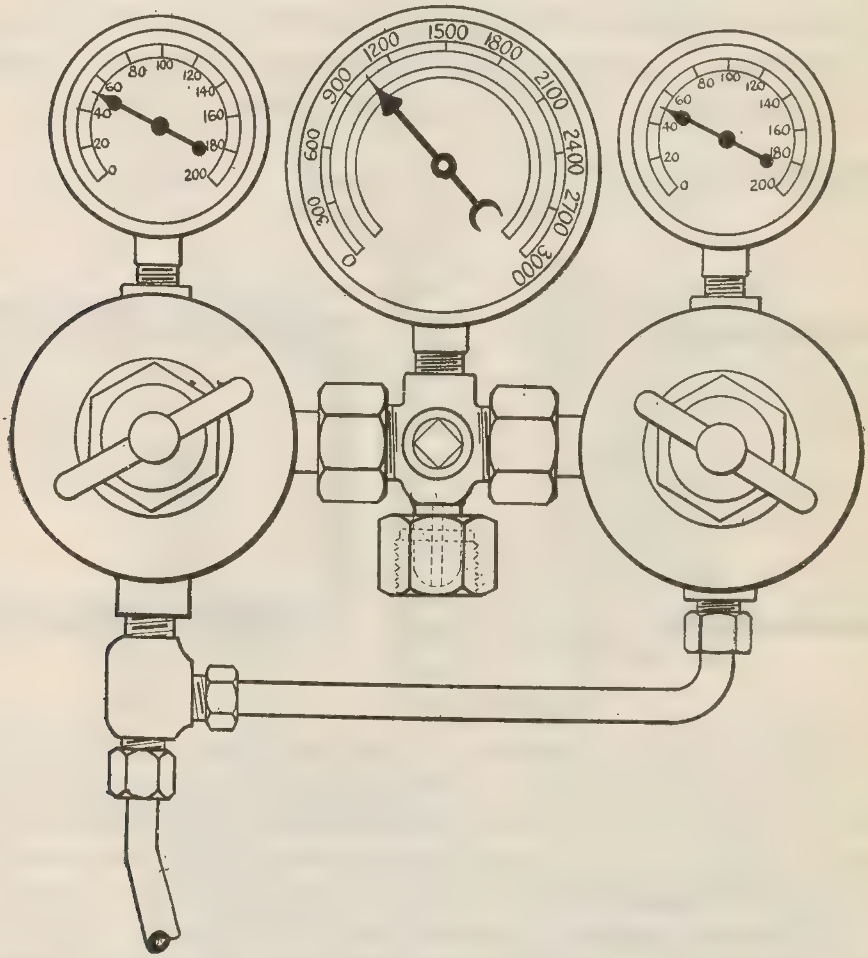


FIG. 10,051.—Bulldog regulator system. Whenever oxygen is used in large quantities such as for heavy cutting, 15 in. and over, double regulator system should be used and preferably with a number of tanks connected to a manifold arrangement.

blow pipe welding, autogenous welding, oxy-acetylene welding, etc., all being more or less accurately descriptive of the same process. Numerous combinations of gases have been used in this process.

Welding of metals consists of joining two pieces of metal.

This is accomplished by heating the edges of the pieces to be joined to a fluid state, and permitting the metals to flow together. No pressure is applied and where necessary, additional metal is added to increase the strength of the weld. Practically all metals used commercially such as steel, iron, cast iron, aluminum, copper, brass, bronze, etc., may be welded by this process. A weld properly made produces a homogenous union and when machined is not visible to the eye.

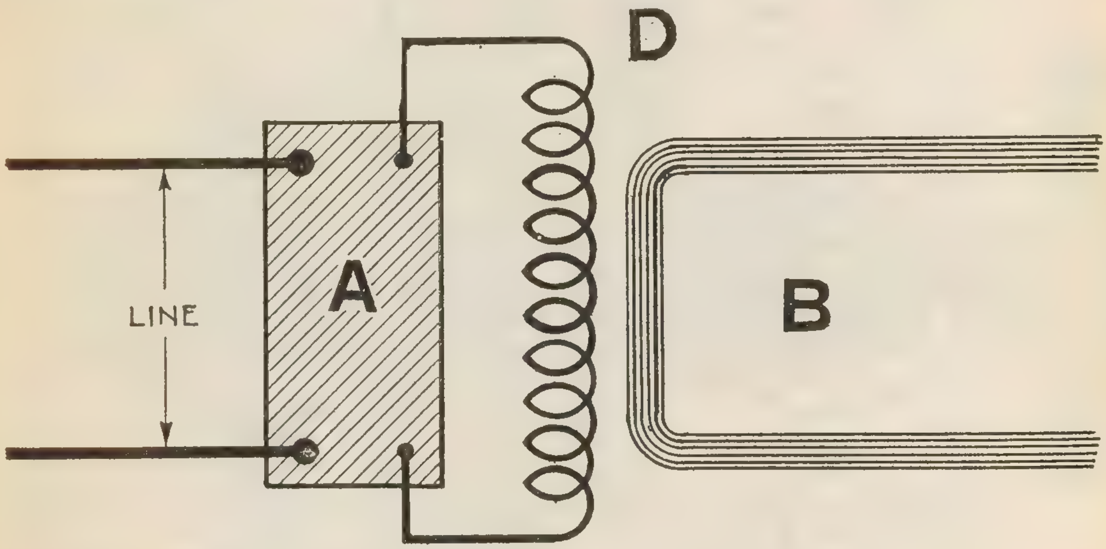


FIG. 10,052.—Welding machine transformer with external voltage regulator. ***In construction,*** the welding machine transformer consists of one turn, the number of turns on the primary winding must be such that line voltage divided by the number of turns would give the desired volts per turn equal to the voltage necessary across secondary. ***For example,*** if line voltage be 220 volts, and the voltage across secondary welding loop should be 5 volts, the number of turns on the primary must be 44. Of course, the magnetic circuit, or core, must be designed suitably for the number of turns—thus obtained, and the primary voltage. It is customary in welding machines to provide means whereby voltage across secondary can be varied. Thus, in case of a machine where maximum secondary voltage, or volts per turn, is 5 volts, it is customary to give means for adjusting the above voltage in several equal steps from 5 to say, 2 volts. The method of regulating the voltage externally as here shown is by impressing upon primary coil voltage smaller than line voltage and of such magnitude that volts, divided by the constant number of the primary turns would give the desired volts per turn. Thus, in order to provide regulation from 2 to 5 volts by this method in case of primary of 44 turns, voltages from 88 to 220 volts must be impressed upon primary coil. This regulation is usually accomplished by means of a transformer, other than welding transformer, called auto-transformer, auto-coil or simply regulating coil.

Welding by this process has been applied to practically all classes of construction and repair work.

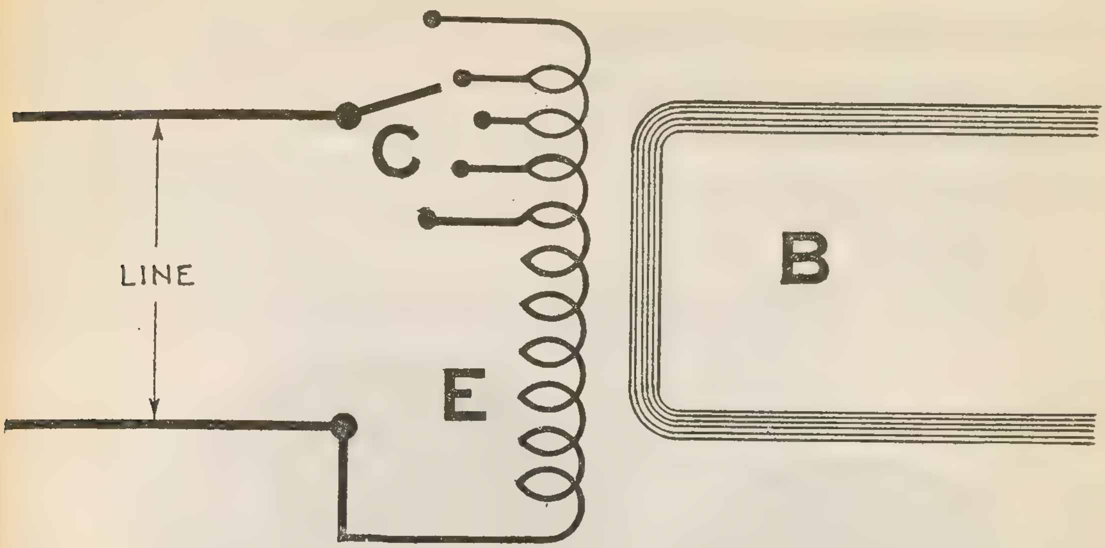


FIG. 10,053.—Welding machine transformer with voltage regulator by variable primary coil. ***In this method*** the number of turns in the primary coil is varied by a multi-point switch similar to that used on battery chargers, permitting a portion of the primary coil to be progressively cut out.

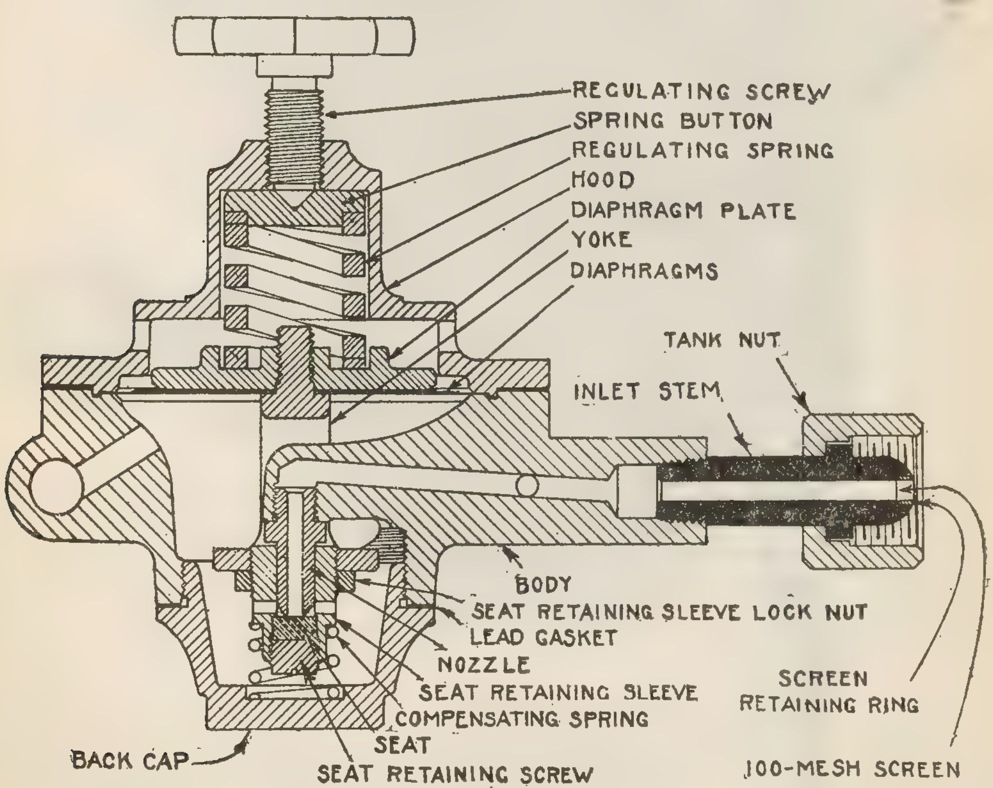


FIG. 10,054.—Torchweld gas pressure regulator; sectional view showing construction and names of parts.

The Importance of Oxygen.—Any combustible gas burning in the open air spreads its flame wide out in order to find the necessary oxygen in the air for its combustion.

If however, the gas be mixed artificially with air, as for instance in Bunsen burners of blast flames, the flame shortens considerably and the heat is more concentrated. The heat effect of the flame is therefore materially increased for a given area. If instead of the air, which contains only 21 per cent oxygen, the rest being nitrogen, the combustible gas be mixed with

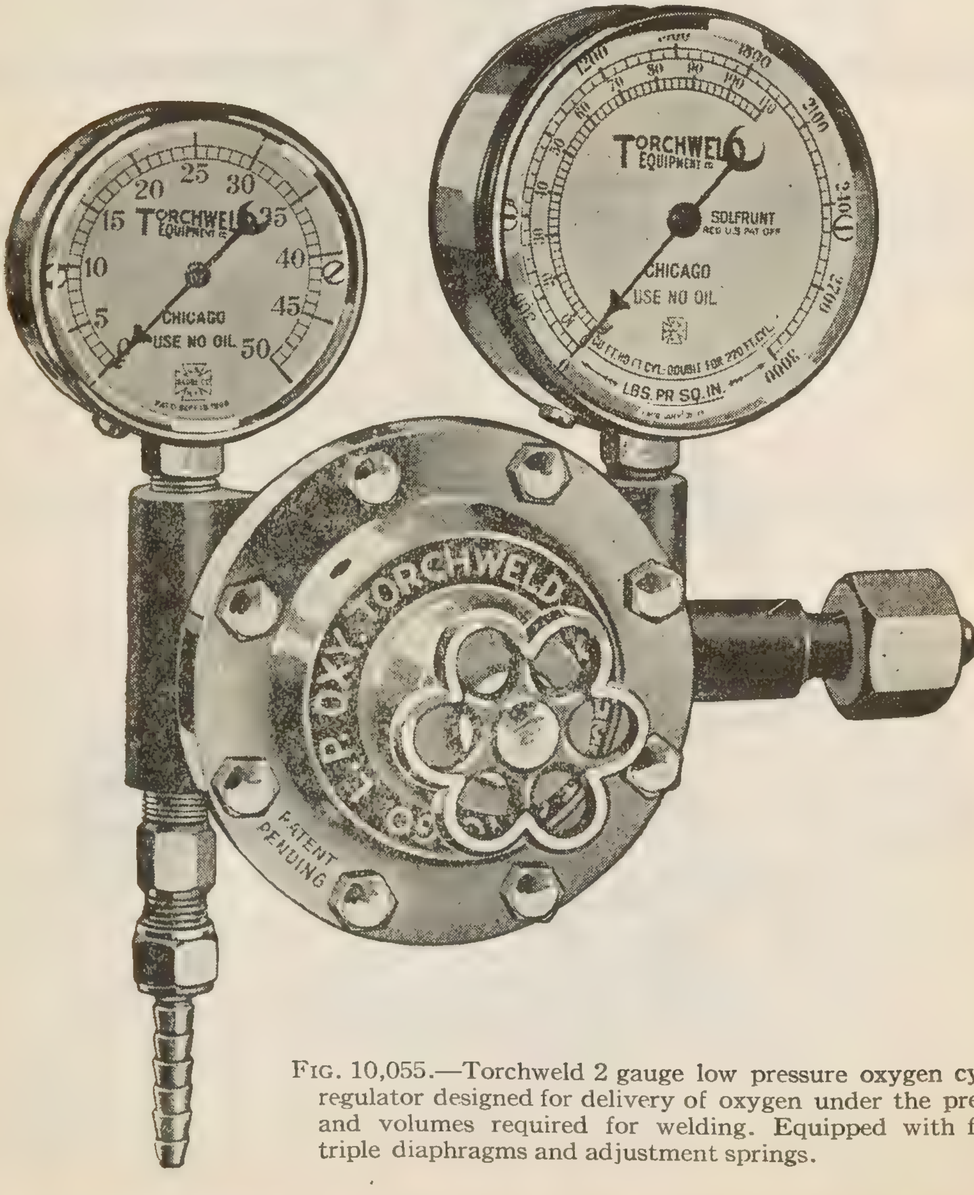


FIG. 10,055.—Torchweld 2 gauge low pressure oxygen cylinder regulator designed for delivery of oxygen under the pressures and volumes required for welding. Equipped with flexible triple diaphragms and adjustment springs.

more, the cooling effect of the nitrogen by the use of pure ogygen is eliminated.

The oxygen therefore acts as a concentrator of the flame. It does not increase the heat value of the combustible gas, it only concentrates this heat to the smallest possible area, just as a magnifying glass concentrates heat rays of the sun to one spot and generates there a very high temperature without being able to increase the heat of the sun rays themselves.

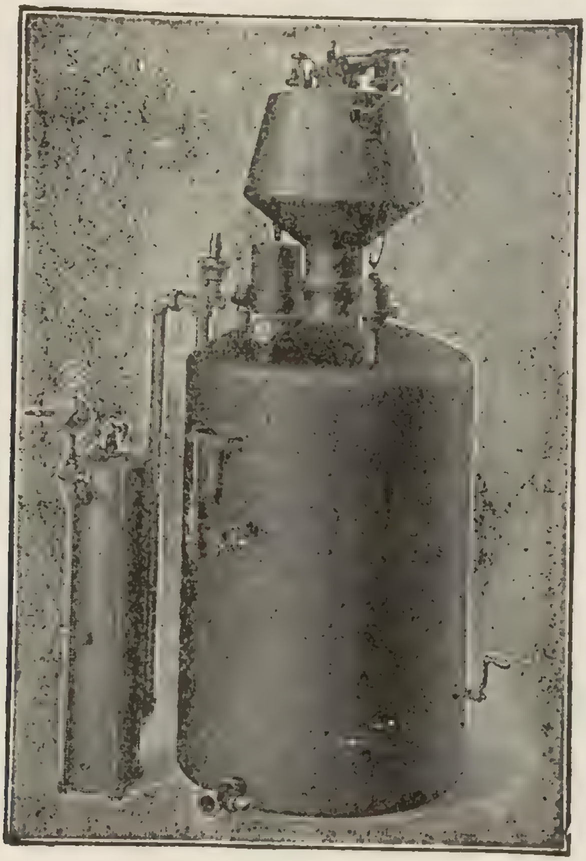
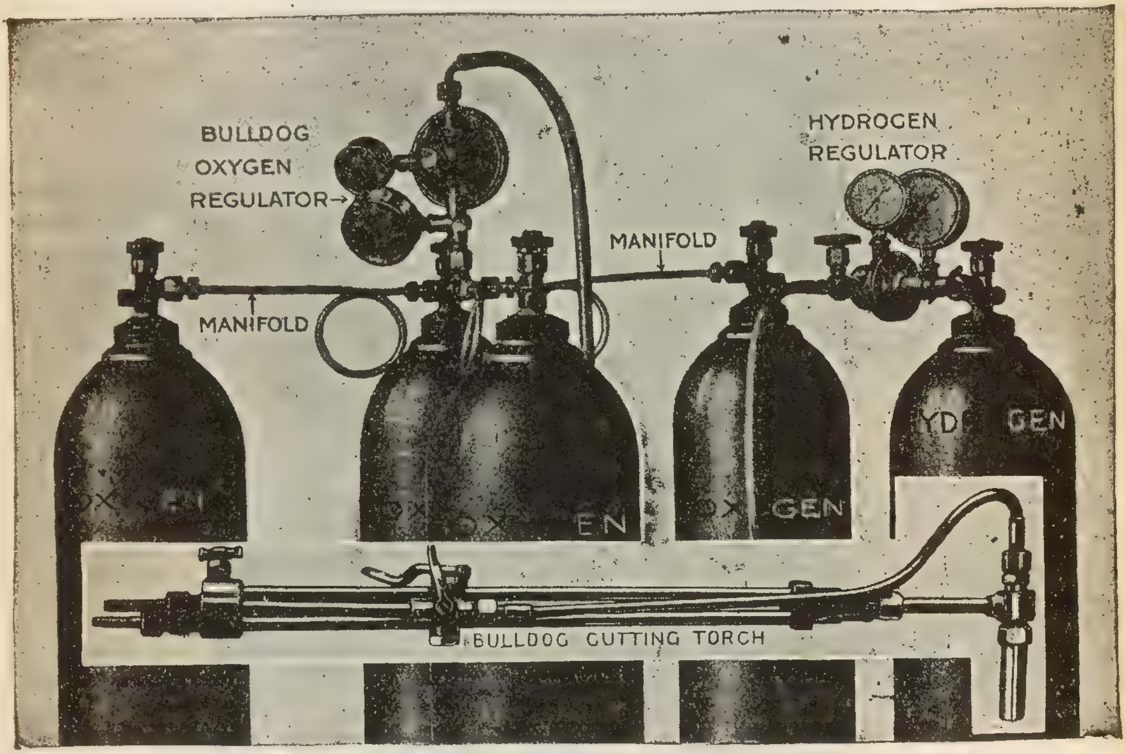


FIG. 10,056.—Torchweld acetylene gas generator. ***The generator*** is of the carbide to water feed type, and the carbide feed mechanism is controlled by a weight driven motor governed by the pressure in the generator maintaining an acetylene pressure of 15 lbs. The gas may be piped over a long distance to welding or cutting stations. The generator, made of steel and welded throughout is equipped with a flash back chamber preventing a possible entry of flame from the pipe line to the gas container. A safety blow off valve insures against excessive pressure remaining in the gas container.

NOTE.—***Torchweld automatic cutting machine.*** This machine automatically guides a cutting torch for cutting various shapes from wrought iron and steel. It is automatically driven by an electric motor, having a reduction gear and friction wheel, driving the disc carrying the tracer shaft, allowing ample speed regulation. The tracer roller moves in a grooved fibre template, causing the torch to exactly reproduce the patterns.

The generating and maintaining of an acetylene plant is not without danger. Therefore it is safer and generally cheaper to purchase actylene from the wholesale manufacturers who ship it in so called safety storage tanks. These drawn steel tanks are completely stuffed with asbestos or a porous mineralizing material and then soaked with acetone. The porous stuffing is necessary in order to distribute the acetylene finely throughout the pores, thus eliminating the dangers of the pressure acetylene, as large free volumes of acetylene compressed to more than 30 pounds might explode and be dangerous. The acetone has the quality of dissolving acetylene to about 25 times its volume at the average temperatures, and this



FIGS. 10,057 and 10,058.—Bulldog oxy-hydrogen cutting equipment. ***It consists of*** 1 oxygen regulator of the double diaphragm type with forcibly guided seat, with 2 gauges. High pressure gauge with solid front and safety release on back. 1 hydrogen regulator of similar construction. 1 manifold to connect 4 oxygen tanks with bulldog oxygen. 1 bulldog cutting torch with 8 interchangeable tips. 1 high pressure hose 2 lengths, 25 ft. each. 1 pair goggles. 1 gas lighter. 2 wrenches. 1 instruction book. It will cut up to 26 ins.

quality is doubled when acetylene is filled in under 15 pounds pressure, and 15 times as high when filled in under 225 pounds pressure; this is the normal pressure under which acetylene is compressed into the safety storage tanks and shipped to users. Acetylene is a vapor and contracts easily with the cold, thus a full tank in cold weather will show only about

150 pounds pressure instead of the normal pressure of 225 pounds when warm. Calcium carbide is sold by the pound, one pound being equal to about 14½ cu. ft. of acetylene.

Cast Iron Welding.—The welding of cast iron pieces is pretty easy so far as the welding operation is concerned.

Chip out or grind out the broken ends so as to form a V when lined up for welding, then heat up with the welding flame both ends of the break, then heat up the apex of the V to the melting point and drop a little cast-iron welding flux into it. This will start the joining. Then add some metal by fusing the ends of the cast iron welding rod into the groove, stirring it lightly into the molten mass and once in a while dipping the welding rod into the flux to make the molten mass run easier together. The flux has not only the quality of making the iron run easier, but also to bring the impurities out of the molten mass making them float on top with the flux.

NOTE.—***The user of acetylene*** has either to purchase at least one acetylene tank outright or enter a service agreement. This service agreement includes that the company will keep the tanks in perfect condition without charge.

NOTE.—***Caution.***—1. Do not store oxygen or acetylene tanks in the sun or near hot places or fires. The pressure in the tanks increases with the temperature and might cause leakages and fires; do not drop full tanks, they might split or crack. Keep full tanks and empty ones apart and send the empty oxygen tanks back to their owners immediately. They are only loaned and it will be necessary for you to pay rental if kept too long.

NOTE.—***Oxygen.***—Commercial oxygen is manufactured either by separating the oxygen from the nitrogen in the air, the air containing 21 per cent of oxygen and 79 per cent of nitrogen, or by splitting the water into its constituents, viz., one part oxygen and two parts hydrogen. In the first process the air is first liquefied, and then the nitrogen, which has a lower boiling point, boils off leaving a commercially pure oxygen as a residue. In the second process, water is decomposed by electrolysis and the two gases—oxygen and hydrogen—carried off into different receptacles.

NOTE.—***The electrolytic oxygen*** is purer and better for welding and cutting, manufacturers being forced, for their safety, to make it at least 99 per cent pure. Besides this, the principle impurity could only be hydrogen, which is combustible. With the oxygen manufactured from air, the impurity is nitrogen and of course not favorable to the welding flame. Nevertheless, both processes of making oxygen have been highly perfected and both are in extensive use. Oxygen is compressed under 1800 pounds into drawn steel cylinders of 100, 150 and 200 cubic feet capacity and shipped to users. Manufacturers of oxygen loan their tanks free of charge for four weeks to the oxygen users, therefore there is no need of buying cylinders.

NOTE.—***Acetylene.***—This gas is generated by the mixing of calcium carbide with water, forming acetylene which goes off as a gas and calcium hydroxide remaining as a precipitate or slush.

Very often it is essential that pieces have to be exactly in line. Then better not V out the breaks or do it only partly so that they can be lined up perfectly. Then tack them on both ends and burn the break out with the welding torch. For this purpose give the flame as much oxygen as it can stand and burn and blow the metal off until it is carved out deep enough to start the welding from. Then regulate the flame back to neutral and start the regular welding.

Of course there are cases where the iron is so dirty or so used up, as for instance, in rusty cast iron boiler sections, that the flux alone cannot clean the metal. In such cases scrape out mechanically with welding rod all the white looking dirt until a clean metal is obtained to weld on. Don't try to weld on the dirt. It will never hold. Often it is more advisable to grind the rusty surface of the break rather than to burn it away. With old boiler sections it mostly pays not to try welding at all because there is only rust left.

Heavier broken pieces should be preheated. There are cases where it is preferable to weld (tack) them provisionally together; to do this, lay them on some fire bricks supporting the piece so that it cannot get out of line, and then preheat it with charcoal, gas or kerosene blast flames.

If there be no economical means to chip out the big breaks, burn them out after the break is preheated to red heat. Take the welding torch with all the oxygen it can stand and burn and blow it out and before starting to weld knock the oxide out with a chisel.

This operation is hard on a torch, and requires frequent cooling of the torch.

Complicated castings showing cracks, for instance, cylinders, should be preheated and kept hot during the welding operation and even a short time after it, and then buried in dry sand or asbestos to cool down slowly. Otherwise they may crack either in the weld or somewhere else. Treat all those pieces the same way as a foundry man would treat them when he casts them anew.

To cover a casting or part of it which has to be preheated, use asbestos paper. This is cheap and keeps the heat wonderfully together. Pile the used asbestos paper bits up to bury welded castings in.

A good welder has to get the cast iron really running and scrape out the impurities before adding new material. Do not be afraid even to spill a little over the sides, but work it together with flux and new metal and stirring the whole mass with the rod. A good welder has to have a little of the brains of the foundry man, to know how to preheat and treat castings, and then he must have a little sense of the mechanic to line up things right, so that they fit after having been welded. Finally, he should know that

only the best kind of welding rods and fluxes give a clean, strong and soft machinable weld.

Malleable Iron Welding.—Under the welding flame, malleable iron shows up quite distinctly as a viscous bubbling mass, showing many holes, hard to weld with either cast iron or steel. Furthermore, successful in welding it with either steel of cast iron, it very often happens that it loses its strength near the weld causing new breaks. For these reasons in the majority of cases, rather braze it with tobin bronze.

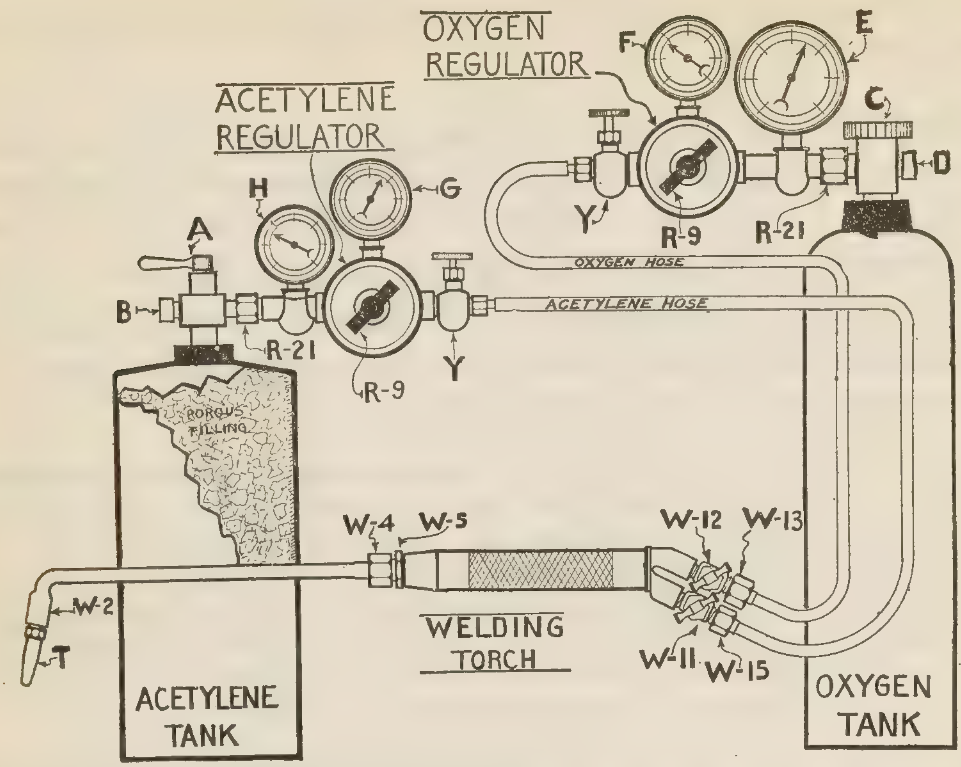
Prepare both ends of the break to V shape and clean the metal thoroughly on both sides of the break and then heat the break so that the tobin bronze connects easily with the malleable iron surface and fills the gap. Do not bring the malleable iron to the melting point, only heat it enough to take the bronze well. This gives an excellent joint and avoids overheating of the iron and its tendency to break near the joint. Use bronze flux and before fusing tobin bronze into the break, drop a little flux over the surface to be welded. After this dip the bronze rod once in a while into the flux.

It is essential that the flame should be just so far distant from the weld as to insure a waterlike running of the tobin bronze. In most cases this distance is about ¾ to 1 inch from the tip end.

But there are cases where malleable iron has to be welded and not brazed, for instance, pieces which have to work in acids or alkalies. Then the only thing to do is to heat the malleable iron piece complete or in part to white heat and to drop it in water for instant cooling. After this operation it takes cast iron without difficulty and can be welded with cast iron using cast iron flux.

Brass and Bronze Welding.—Small pieces can easily be welded in the regular way, using tobin bronze rods and flux. The chief thing to remember is not to fuse in metal before the original piece is hot enough to take it like water, and to hold the flame about ¾ inch to 1 inch distant. If the flame be not hot enough, rather take a larger tip.

Heavier pieces, for instance, larger bronze pump cylinders, have to be excellently preheated, as brass, bronze or copper carry the heat so fast away that even the hottest welding flame would be insufficient.



FIGS. 10,059.—G. W. & E. welding equipment ready for operation. ***Instructions:*** Loosen regulating handle R-9 of the acetylene reducing valve, turning it to the left and then open tank valve A, of the acetylene tank slightly. Then smell around tank in order to find out if there be a leak. Should there be any leak, it is either in coupling R-21 which should be tightened more, or it may be in the tank valve itself, if so, tighten packing nut. If everything seem tight, open tank valve wide and turn handle to the right until gauge H, shows about 10 lbs. pressure, or for very heavy work up to 25 lbs. pressure. Then open shut-off Y, leaving needle valve W-11, closed. As a final test, to make sure that there be no leakage anywhere, close tank valve A, for a moment and see if either gauge G, or gauge H, drop off quickly in pressure. Should G, show a decrease, then there is still some leak either in coupling R-21, or in the tank valve packing, or in gauge G. Should gauge H, show a decrease, there is a leak between Y and W-11. Eliminate these leakages before starting and make this test every morning or whenever a new tank is connected. Do the same after connecting the oxygen reducing valve with coupling R-21, to the oxygen tank. If everything be tight, keep reducing valve regulated to between 10 and 40 lbs. pressure according to the heaviness of the work. Always open oxygen cylinder valves wide so that the flow of oxygen is not obstructed. Oxygen cylinders and acetylene cylinders have safety plugs D and B. Do not touch them. They are there to release the gas safely, should there be exceptional conditions as excessive heat or fire. To start the flame, turn on acetylene by opening needle valve W-11, and light it. Add acetylene until the flame leaves tip to about ⅛ inch. Then open needle valve W-12, adding oxygen to the flame. The white glare of the spread-out acetylene flame will diminish and the flame itself shorten. Continue adding oxygen, slowly, until a nice bright cone inside a bluish flame is visible. As soon as this cone is getting clear-cut (about ½ inch long), the flame is right burning with a neutral mixture. If more oxygen be added the cone will get shorter but the flame is oxydizing, if less oxygen, the cone loses its compact, clear cut shape and gets carbonizing. Only the neutral flame is good for welding. The heat of the flame may be increased by adding acetylene and oxygen step by step, so long as the flame does not blow off the tip end.

In welding thin sheets with upturned edge seams, weld down the upturned edges, using a little flux but no additional metal; with overlapped seams, weld the overlapped ends together after applying some wet flux to the joint.

If the sheets be very thin, protect them on both sides either with wet asbestos paper or with two copper bars, leaving only the seam to be welded free. The thinner the sheet the more the angle that the flame must be applied in order to avoid the burning of holes.

The same applies to copper (or steel or aluminum) welding, but as red hot copper is quite an absorber of gases, wet the seam and both sides with a flux which, when running, covers the surface of the copper and prevents gases getting into the metal. A little hammering of the red hot weld makes the weld homogenous.

Steel Welding.—Wrought iron and steel welding is perhaps the largest field for welding as it is mostly used in the manufacturing line, such as for tanks, kettles, frame and pipe work, etc.

This material is very sensitive as to the right welding flame and you have not only to regulate the flame by the looks of it, but as to how it affects the metal. The flame may look all right, but applied to the steel care must be taken to get a clean, clear running metal. In other words. final adjustment of the flame by watching the molten metal. A flame which does not produce a clean and clear molten metal is not right. Watch the molten mass continuously in order to be sure of the quality of the work. If the flame be not right, there may be bubbles or foaming, which means that the metal is absorbing either carbon or oxygen. Both are detrimental.

Mild steel as used for tank, piping, etc. is easy to weld with a well adjusted flame using as a filler a first class Norway iron. V-out the pieces to about 45 degrees and bigger pieces to 60 degrees on one side or on both sides and play the flame over the sides and apex till the original material runs well together, then add from filler, but be sure that the spot on is in complete fusion before filling. Molten steel is a little sticky mass, a circular movement with the torch is necessary to spread it in evenly. If maximum strength be a chief item hammer lightly the red hot weld with a tiny hammer when an inch of welding is finished. This makes the weld very homogeneous.

In many cases it is essential to heat up the welded piece to about 1,300 degrees F. once more, after it is cold, and then let it cool down once more.

The structure of the weld will then be much finer than without this annealing.

Heavy steel breaks have to be preheated to a high red heat before welding, and for very heavy breaks, it is even advisable to use two welders and two welding torches to work simultaneously whenever feasible.

FIG. 10,060.—G. W. & E. oxy-acetylene torch cutting large shaft.

Many failures in welding heavy steel pieces are caused by the fact that the surrounding material is not hot enough to insure a proper joining with the fused in metal. It may look all right during the welding operation, but it only binds provisionally and loosens when cooling. Therefore, if possible, use two torches even on preheated pieces.

Tool steel and other quality steels are hard to weld and need an experienced welder who can judge from the appearance of the molten mass. For instance, with welding high speed steel to lower grade steel shanks, first V-out both pieces, and set them into the right position and heat them red hot. Then start welding. At first there will be little difficulty, but when near the face, the high speed steel will act under the flame like malleable iron. In some cases where the cutting edge is a little removed from the joint, it is advisable to finish the upper part of the weld with tobin bronze, but when rehardening the edge be careful not to melt away the bronze.

Aluminum Welding.—A difficulty experienced in aluminum welding, is that it oxydizes readily on the surface forming a skin over the molten metal. This oxide has to be broken either mechanically by stirring it off (puddling) or by using a special flux with the welding rod. The best way to weld an aluminum crack is to first puddle the metal together, then to fill in with a welding rod and flux and then puddle the whole of it over again when finishing a short length.

Aluminum has no strength at all when heated up to the melting point, therefore it has to be supported either by a fire clay backing or by a plaster of paris mould. Right here must be mentioned that one of the greatest difficulties with commercial aluminum, especially in crank cases, is its composition. Very often it contains an excessive percentage of zinc, and the more zinc the more skill needed to make a good job.

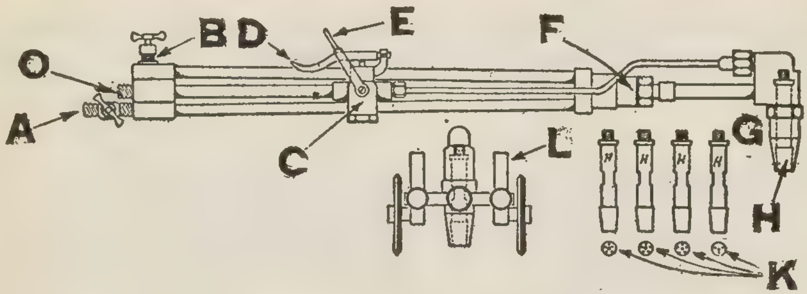
There are some general instructions about welding crank cases. Some people prefer to heat the cases up slightly before welding them, others do them cold.

With preheated cases strap them with suitable irons and bolts so that they cannot get out of line. This is not absolutely necessary if the case be welded cold and there are many experienced welders who prefer the latter process.

In case there be a crack or break in the middle part of the case shell not continuing to the edge, saw into the case from the edge into the crack. Then start the welding from the crack to the edge. It is often advisable to open the crack near the edge slightly with a wedge. Coming near this wedge, remove it and finish the weld, thus allowing for contraction. In some instances where there is no special strength necessary, these cracks can be soldered, but look out for very soft solder which does not need too

much heat to run. V-out the crack, then rub the solder in on both faces of the crack with a suitably hot iron and then fill it up using soldering iron.

Cutting with Oxygen.—This operation is based on the fact that steel or iron (not cast iron) brought to the melting point



FIGS. 10,061 to 10.066.—C.W. and E. cutting torch and tips; O, oxygen inlet; A, acetylene inlet; B, oxygen valve; C, lever key; D, lever, E, lock; F, mixing chamber; G, copper nozzle; H, cutting tip; K, tip end. The cutting oxygen is applied through lever key C, by pressing down lever D. Lock E, can hold the lever down so that the operator need not tire his hand in case of long cuts. The mixing chamber F, is for the preheating gases. These flow into the torch head and come out of the 3 or 5 holes arranged in the circle at tip end K. In the center of the tip end there is one more hole through which pure oxygen shoots as soon as lever D of lever key C is pressed down. The tip H, is protected against excessive heat and wear by a copper nozzle G.

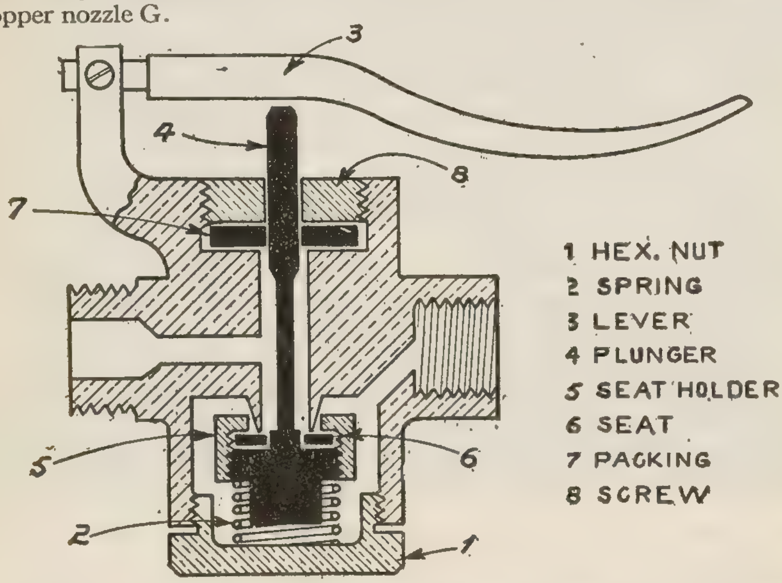


FIG. 10,067.—C. W. and E. lever key; detail view showing construction. The leather washer seat 6, must be renewed as soon as oxygen leaks through center hole of cutting tip when lever key is closed. To replace seat, remove hexagon 1, take out spring 2, and push out plunger 4, screw off seat holder 5, and exchange leather seat 6, for new one, and put everything back in its place. Whenever cutter is connected wrong by screwing oxygen line to acetylene inlet, seat 6, in lever key might burn out.

will burn rapidly when subjected to a jet of oxygen and generating, by this combustion, a tremendous temperature.

To do cutting, the starting spot has to be heated up to the melting point and then a jet of pure oxygen has to be blown on this spot. To heat up this spot, a torch is used having one or more very hot preheating flames, such as oxy-acetylene or oxy-hydrogen welding flames. In order to concentrate these flames to one spot, they have to be as near together as possible. There are generally three to five flames coming out of a tip with three to five holes placed in a circle of small diameter. In the center of this tip there is one more hole through which the pure oxygen jet can be applied.

As soon as the starting point is sufficiently hot, the oxygen jet is turned on and can then hit exactly the center of the preheated spot and start the cutting, burning away the iron in its path and generating through this initial combustion such a terrific heat that the oxygen finds hot enough spots all the way through its path, so that the cutting operation continues through the whole thickness of the iron or steel.

The pressure of this oxygen jet has to be sufficient to furnish enough oxygen for the burning up of the iron in its path, and also to blow out the burnt material (oxide).

By moving the cutting torch slowly in the direction of the intended cut, a fine slot of 1/16″ to 1/8″ width corresponding to the width of the oxygen jet will be burnt out, thus cutting the piece straight through.

The finer and more compact (sharper) the oxygen jet, the finer the slot. The steadier the cutter be moved at the right speed, the cleaner the cut. A cutter moved by a machine, that is to say, absolutely steady and at a uniform speed, will show cuts as clean as with a saw and do the work incomparably quick and in any direction. Speeds of one foot a minute for one-inch stock can easily be attained by a mechanically moved cutter.

Of course a man with a good steady hand can often cut as fast or even faster than a machine. 6½ in. thickness has been cut at the rate of 3 minutes per linear foot, and 20 in. shafts have been cut in 18 minutes.

Gases used for Cutting.—By far the greatest part of ordinary cutting is done with oxygen and acetylene as a preheating flame.

NOTE.—***Use no oil or grease*** on any part of a welding or cutting equipment as oxygen and oil or grease might cause an explosion.

Only when it comes to cutting heavier thicknesses hydrogen is preferable. For cutting really heavy stock, 12″ and up to 30″, pure hydrogen is the only gas which gives results.

For cutting in confined places such as inside boilers a less explosive gas than either acetylene or hydrogen is preferable for instance, one of the many compressed oil gases. The reason is that in those places the hose might get damaged by flying sparks and the gas excape and burn; in this case it is much safer for the operator to face a lazy burning and very little explosive gas than acetylene or hydrogen.

Cast Iron Cutting.—Contrary to statements of people who know better, cast iron cannot be cut.

It can be melted and burned out in a slow way using an excessive amount of gases and requiring an asbestos armoured and specially trained operator, immune against heat, sparks, burns, etc. Use a welding torch and give it all the oxygen it can stand without blowing the flame out, or burn it through with a carbon arc.

CHAPTER 154

Gas Engines

The term gas engine is generally understood to mean an internal combustion engine using natural gas or the vapor of gasoline for fuel as distinguished from "oil" engines or those using kerosene or heavy low grade oils, the latter class including the Diesel engine.

The Cycle of a Gas Engine.—The term "cycle," as applied to an engine, is defined as a *series of events which are repeated in regular order, constituting the principle of operation.* These several events comprise the transformations which take place in the working medium, or, with reference to the gas engine, the distribution and behavior of the fuel mixture in passing through the engine.

The gas engine derives its energy from the heat, generated by the combustion within its cylinder, of a ***mixture of fuel*** in the form of a gas or spray mingled with air in proper proportion to form an explosive mixture.

The mixture is admitted to the engine intermittently, and the amount supplied at each admission is known as the ***charge.***

The combustion of each charge takes place under pressure attained by ***compression***—a result of the inward movement of the piston after the charge is admitted and all valves closed.

The effect produced by igniting the mixture after compression is commonly called an ***explosion,*** which is simply a quick burning or rapid combustion of the mixture.

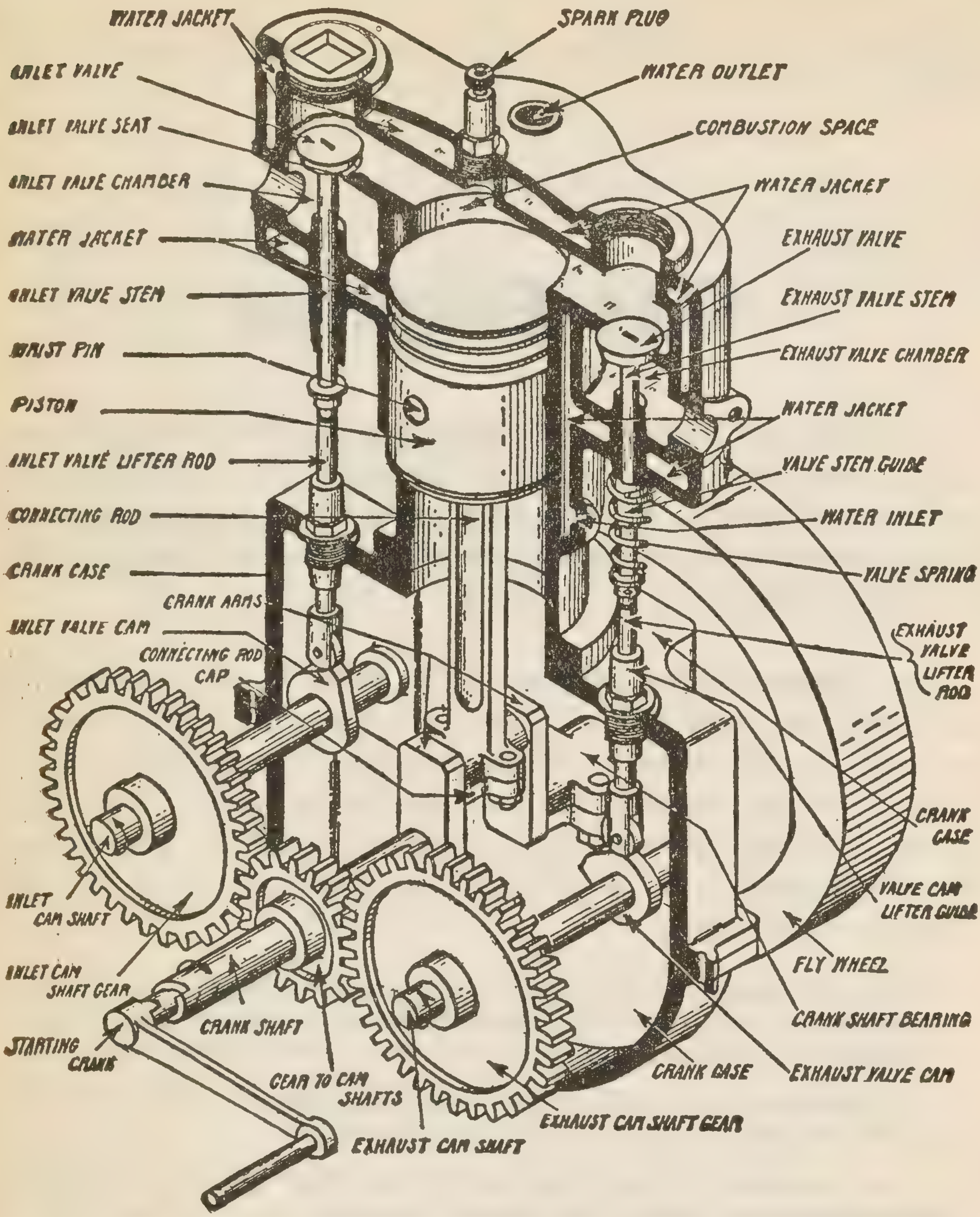


FIG. 10,068.—Sectional view of a four cycle gas engine, showing the valve gear and other working parts. Both inlet and exhaust valves are mechanically operated. The location of the valves diametrically opposite each other requires a separate cam shaft for each. These cam shafts are geared to the engine crank shaft and they make one revolution to every two of the engine. When the inlet valve is operated by a spring and the engine suction, only one cam shaft is necessary, as shown in fig. 10,069.

This sudden explosion causes a high degree of heat within the combustion chamber, resulting in considerable initial pressure, and gives to the piston an ***impulse,*** which decreases in intensity while the piston advances to make the ***power stroke,*** by reason of the expansion of the gases.

The products of combustion are finally ***exhausted*** from the cylinder.

Expressed briefly, the cycle of a gas engine embraces: 1, the

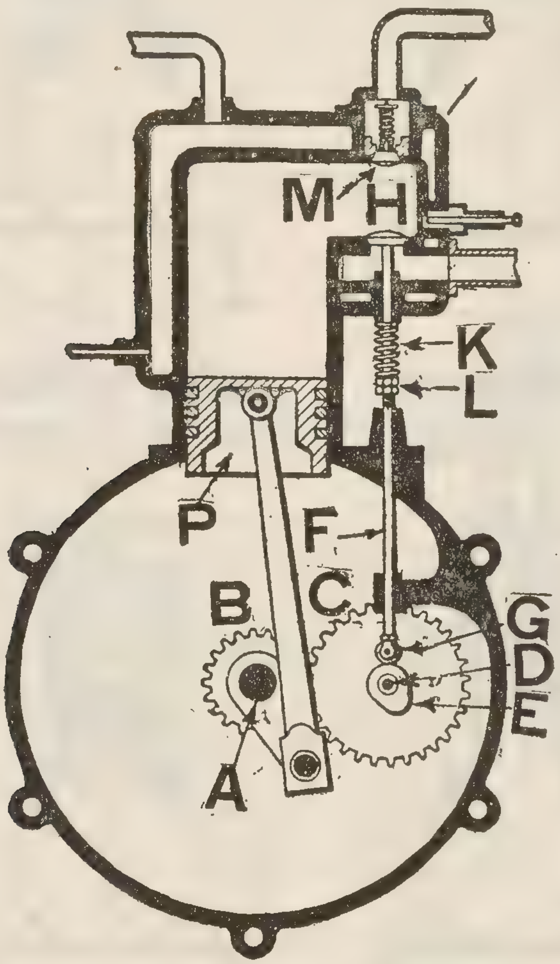
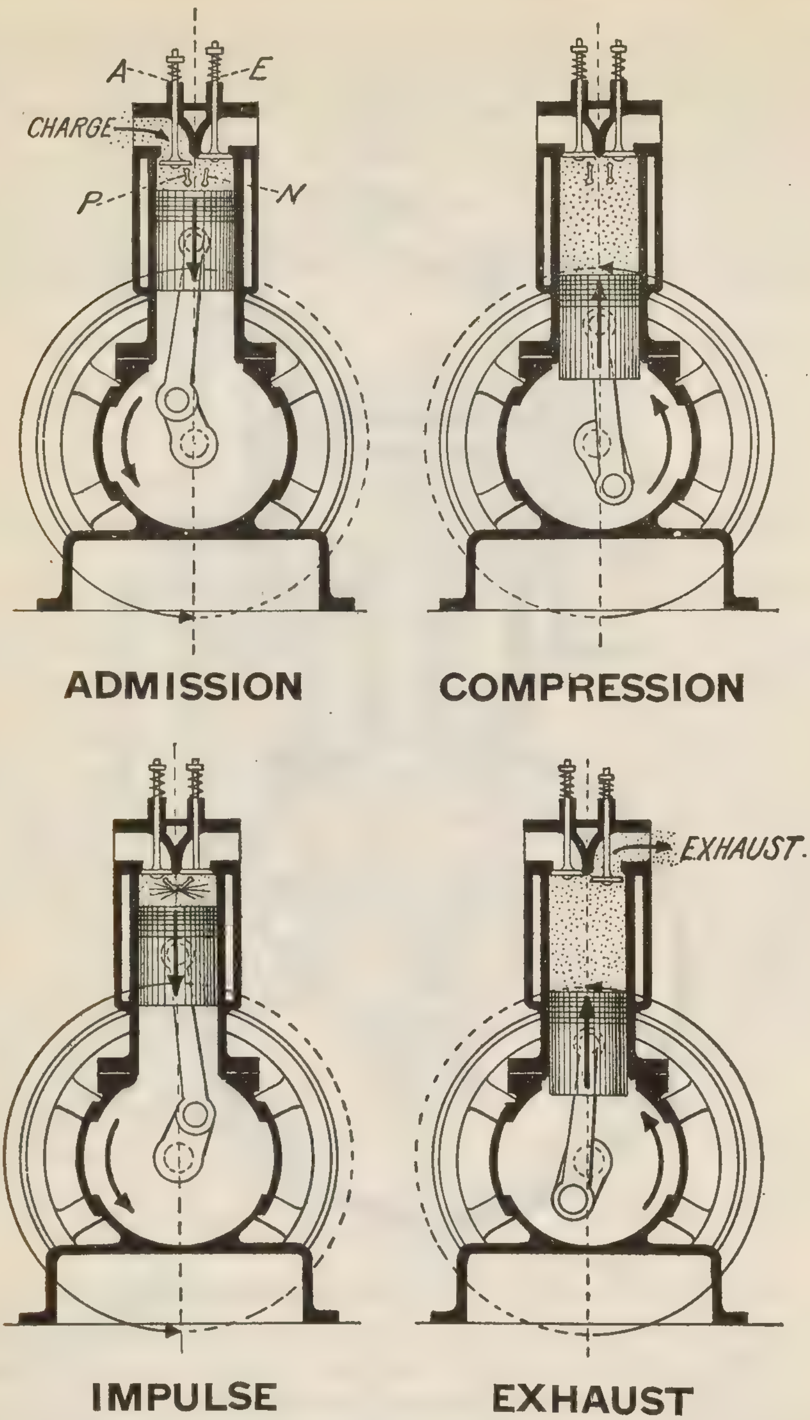


FIG. 10,069.—Illustrating the operation of a four cycle engine with spring inlet valve gear. The figure shows a spring actuated inlet valve M, and a mechanically operated exhaust valve H. The latter is opened when the cam E, revolves and raises against the roller G, which is on the bottom of the lifter rod F. The rod F, extends upward and rests against the bottom of the stem of the valve H, although between the two or at their point of contact are nut and lock nut L, for lengthening or shortening the lifter F, and so to vary the time of opening or closing of the valve. The spring K, is compressed or squeezed together when the valve is opened and immediately the cam E, travels around and allows the roller G, to fall this spring exerts its pressure and closes the valve. The intake valve M, is automatically opened by the suction of the engine.



FIGS. 10,070 to 10,073.—The ***four cycle*** method of operation. Fig. 10,070, ***admission*** stroke; fig. 10,071 ***compression*** stroke; fig. 10,072, ***power*** or ***impulse*** stroke; fig. 10,073, ***exhaust*** stroke. A, is the admission valve; E, exhaust valve; N, negative electrode; P, positive electrode of igniter.

admission of the charge into the cylinder; 2, its compression; 3, ignition; 4, combustion; 5, expansion therein; and 6, the subsequent exhaust of the products of combustion.

In the operation of a gas engine, the number of strokes required to complete the cycle varies with the type of engine. The cycle is usually extended through four strokes, although in the small sizes it is usually completed in two strokes. Engines of these types are known respectively as ***four cycle*** and ***two cycle.****

The Four Cycle Engine.—This engine, although more bulky than the two cycle engine, and requiring twice the number of

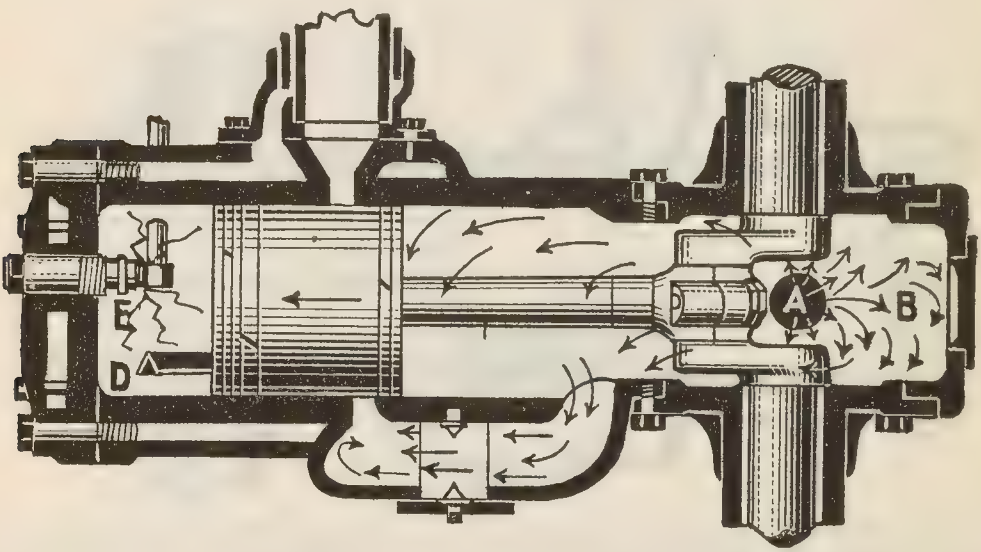


FIG. 10,074.—The two cycle engine; ***first stroke.*** The inward stroke of the piston induces a charge of the mixture at A into the crank case B, and compresses the previously admitted charge into the cylinder D; the subsequent ignition takes place at E.

cylinders for equal turning effect, is almost universally used except in small sizes; it has some advantages over the two cycle engine, which have more than offset its undesirable features, and caused it to come into general favor. Among the advantages which may be mentioned are: efficiency, flexibility,

*NOTE.—These terms have been criticised by some as incorrect; they are conveniently and properly applied to the gas engine when considered as abbreviations for four stroke cycle and two stroke cycle

adequate admission at high speeds, higher degree of expansion, and more efficient exhaust.

The cycle is as follows:

1. First stroke (outward) *admission;*
2. Second stroke (inward) *compression;*
3. Third stroke (outward) *expansion;*
4. Fourth stroke (inward) *exhaust.*

The Two Cycle Engine.—This engine is built usually in small sizes, the essential difference between it and the four

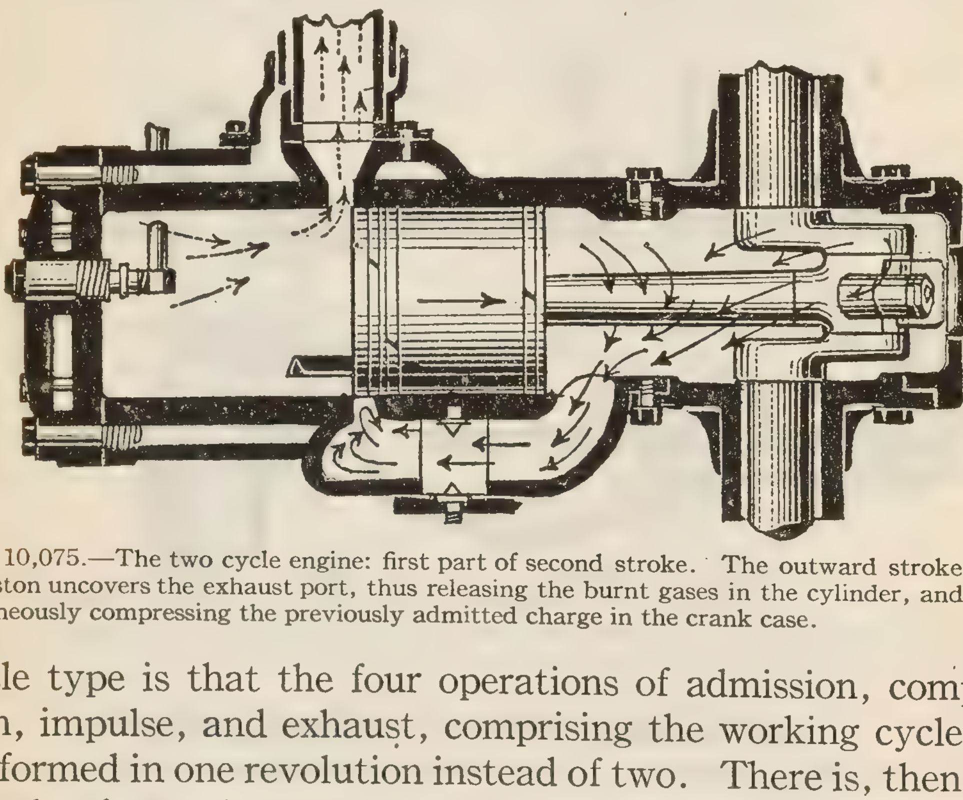


FIG. 10,075.—The two cycle engine: first part of second stroke. The outward stroke of the piston uncovers the exhaust port, thus releasing the burnt gases in the cylinder, and simultaneously compressing the previously admitted charge in the crank case.

cycle type is that the four operations of admission, compression, impulse, and exhaust, comprising the working cycle, are performed in one revolution instead of two. There is, then, one impulse for each revolution. From this, it follows that the weight is much less than that required for the four cycle engine.

The necessary mechanical features for two cycle operation are as follows:

1. An enclosed crank case fitted with a valve arranged to

open and admit fuel mixture at the front of the piston, on the inward stroke.

2. Inlet and exhaust ports located near the extreme outward position of the piston, so that they will be uncovered during the outward stroke.

3. A by-pass tube connecting the interior of the cylinder with the crank case, so as to admit the charge at the proper point in the cycle.

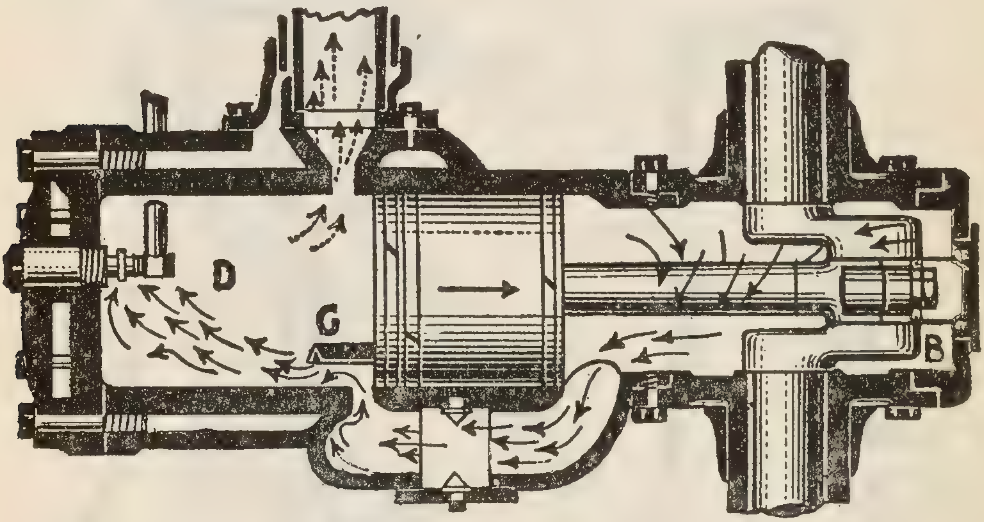


FIG. 10,076.—The two cycle engine; *end of the second or outward stroke.* The gases compressed in the crank case are admitted to the cylinder space D, through the open inlet port, and sometimes past the screen or deflector C. The passage between the cylinder and the crank case is controlled by a butterfly valve, which here is shown open.

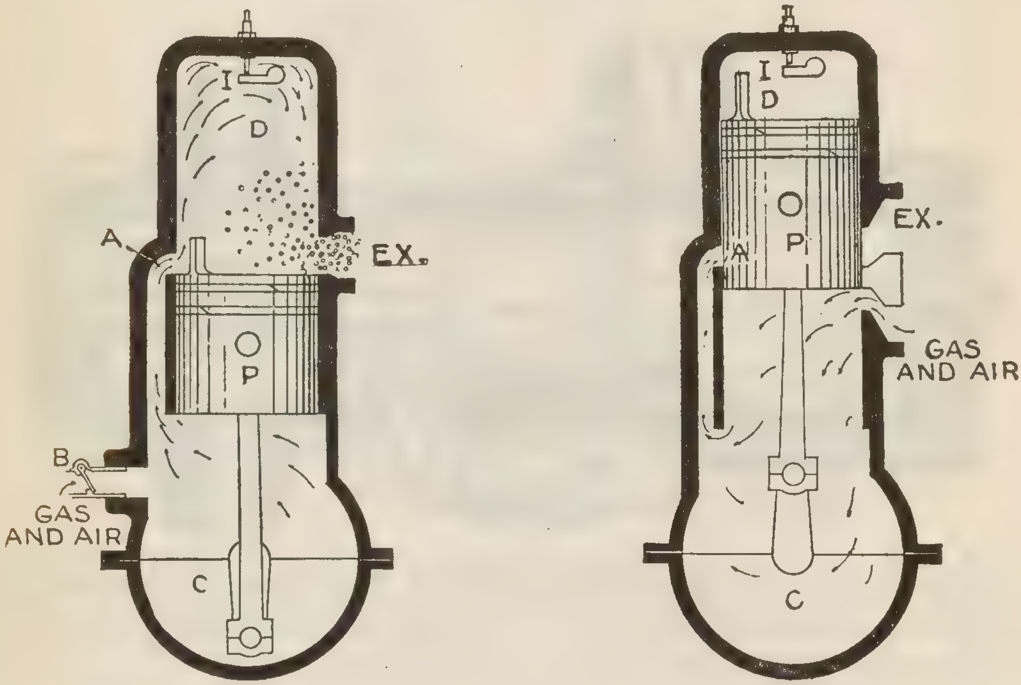
The cycle is as follows:

First Stroke.—The piston moves inward and draws in a charge of the explosive mixture into the enclosed crank case. During the operation the charge previously admitted to the cylinder is compressed and ignited as the piston nears the end of the stroke as in fig. 10,074.

Second Stroke.—The pressure caused by the explosion of the charge drives the piston outward, and slightly compresses the mixture drawn into the crank case during the previous stroke as in fig. 10,075. Near the end of

the stroke the piston uncovers the exhaust port and the burnt gases are exhausted. During the remainder of the stroke the piston uncovers the admission port, as in fig. 10,076, and the new charge, previously compressed in the crank case, is admitted to the cylinder, being deflected upward to the head end of the cylinder by a screen or "deflector plate" set in the end of the piston.

The four cycle engine is the more economical because with the cycle extended to four strokes, there is more time for admission and exhaust; since these events take place at separate



FIGS. 10,077 and 10,078.—Sectional views of Palmer two cycle engine showing difference between the ***two port*** and ***three port*** types. Fig. 10,077, two port engine; fig. 10,078, three port engine. In the three port engine when the piston is at top of stroke a vacuum is created in base (see fig. 10,078). Inlet port, marked *gas and air*, is opened, allowing a charge to enter crank case. When piston starts down, this port is closed. The mixture of gas and air in crank case C, is then compressed by the downward motion of piston. Transfer port A, is opened, allowing gas and air which has been mixed in crank case to pass into cylinder. On the downward or explosion stroke the exhaust port opens slightly before transfer port and the exhaust or burned gases are passing out as a fresh charge is coming in through transfer port. To prevent this incoming charge passing across piston and into exhaust port a baffle plate D, is placed on top of piston which deflects a charge of incoming gas to top of cylinder. Piston comes up again closing exhaust port and transfer port and mixture is exploded. In the two port type, fig. 10,077, a check valve is used in place of the third port as shown.

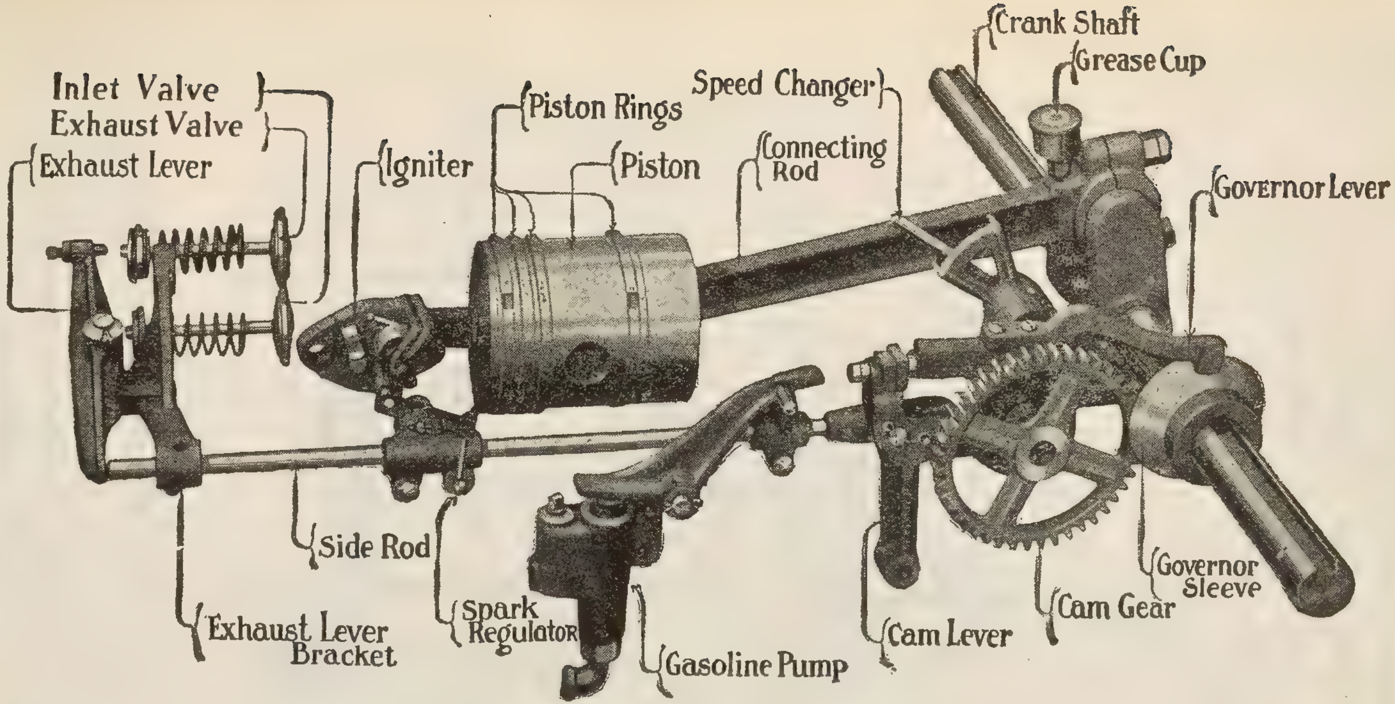


FIG. 10,079.—Working parts of Alamo four cycle engine.

intervals, no chance is given for any of the charge to escape past the exhaust valve while open. Owing to simultaneous admission and exhaust in the two cycle engine, *pre-release* of the burnt gases must take place earlier than in the four cycle engine, resulting in a loss of power which is avoided in the latter. The inefficiency of admission and exhaust of the two cycle engine becomes more marked at high speeds.

Carburetters.—A carburetter is a vessel in which the gasoline is vaporized and mixed with air, prior to its introduction into the power cylinder, and the highest fuel efficiency is obtained from the use of such devices as those which will completely saturate the air with gasoline vapor.

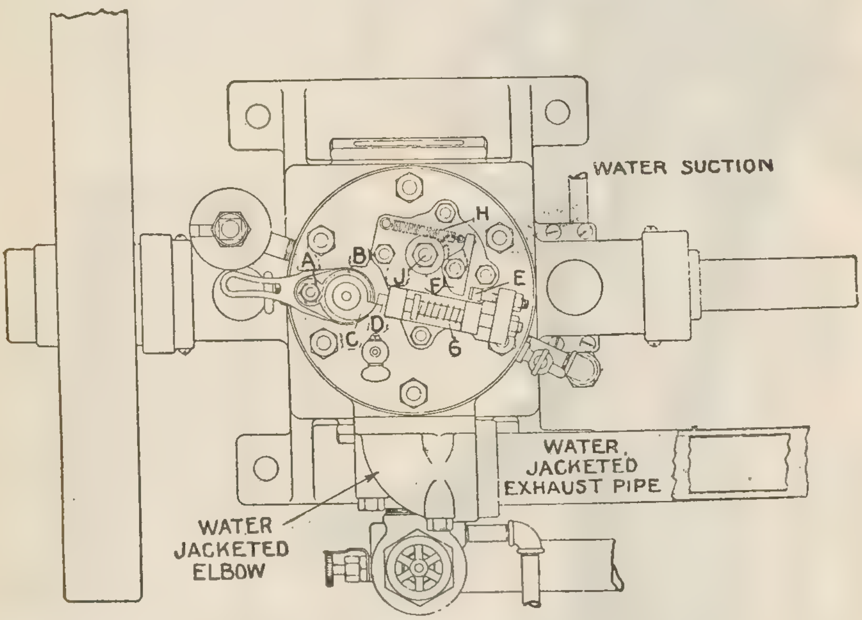


FIG. 10,080.—Plan of Fay and Bowen two cycle engine. ***In construction,*** the smaller gear A, is attached to the igniter shaft, and turns with it. The gear drives a larger gear B, the teeth of which show around and below the cam C. ***In operation,*** as the igniter shaft turns, this larger gear B, turns the cam C. The cam C, pushes back the plunger D, and as the plunger D, slips off the point of the cam C, its other end or hammer E, strikes the movable electrode F, breaking the electric current, and producing a spark. In the illustration, the relation of the electrodes and sparking points *inside* of the firing chamber is indicated by dotted lines, the spring H, brings the movable electrode F, to its place again, when the plunger D, backs off for the stroke.

The Mixture.—For stationary engines which operate at unvarying speed, the carburetter may supply the mixture of gas and air in constant proportions. With the automobile engine, however, the conditions are quite different, and it has been determined from experience and numerous experiments that a

constant mixture is not advisable from either the standpoint of fuel economy or best operation. Inasmuch as ignition conditions vary with the speed of the engine and the compression

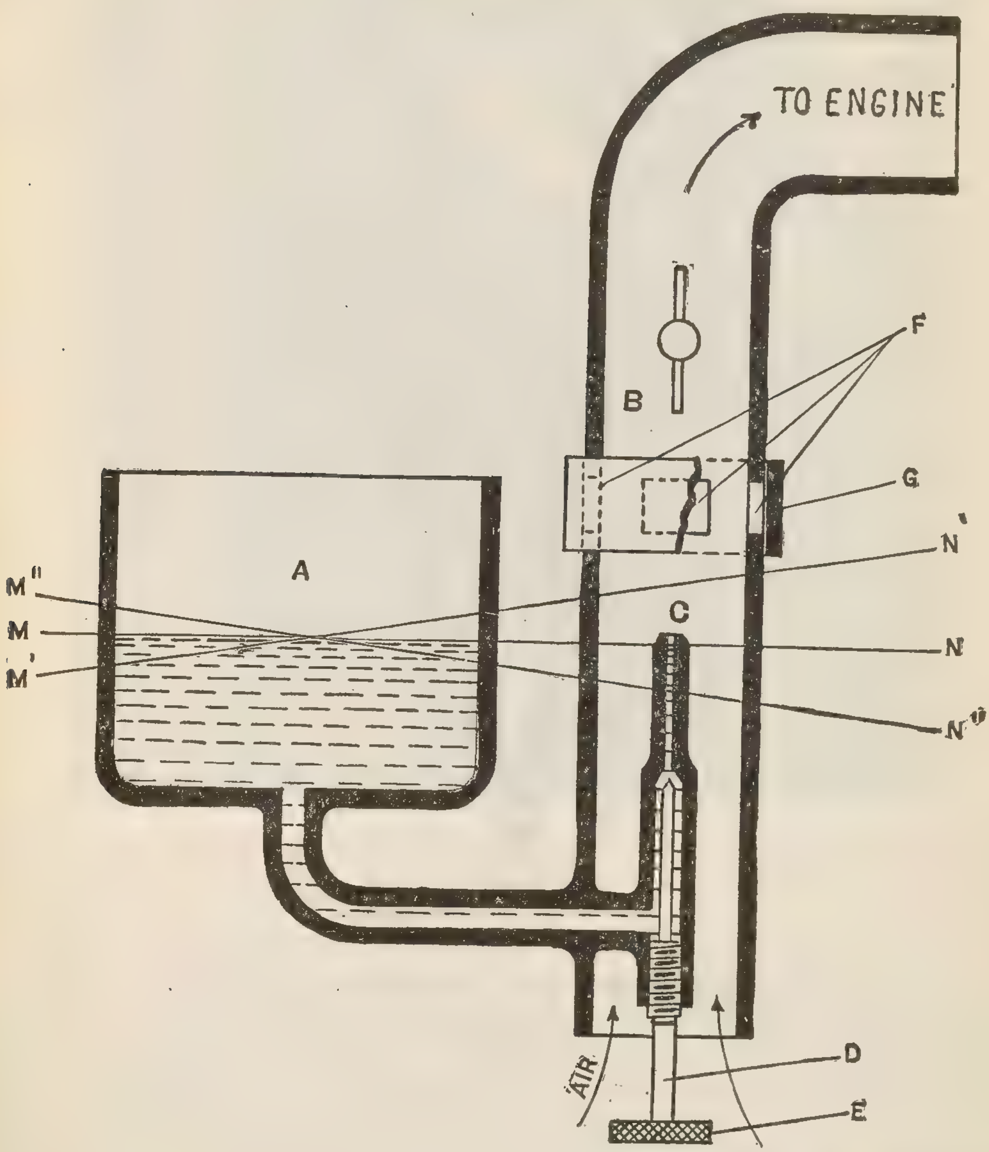


FIG. 10,081.—A rudimentary, or simple form of spray carburetter illustrating the principles of operation employed in the modern device. A, is the receiving chamber, B, the mixing chamber. A connecting passage conveys fuel to the spray nozzle C, controlled by the needle valve D, by turning the thumb wheel E. Air enters through the primary passage in the base and through the auxiliary ports F, the latter being adjustable by the sleeve G, and the mixture to the engine, controlled by a throttle located above the sleeve.

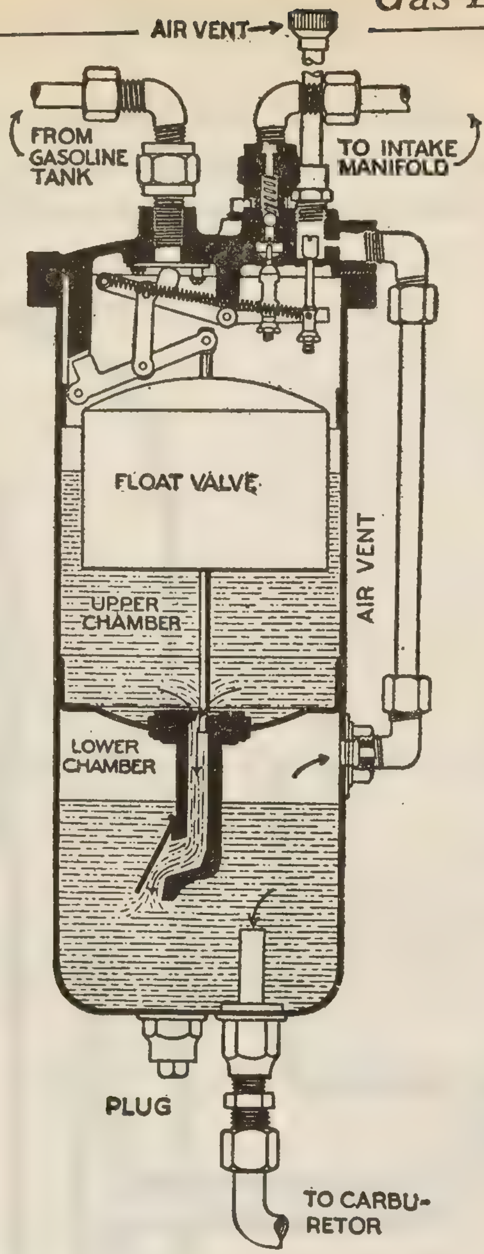
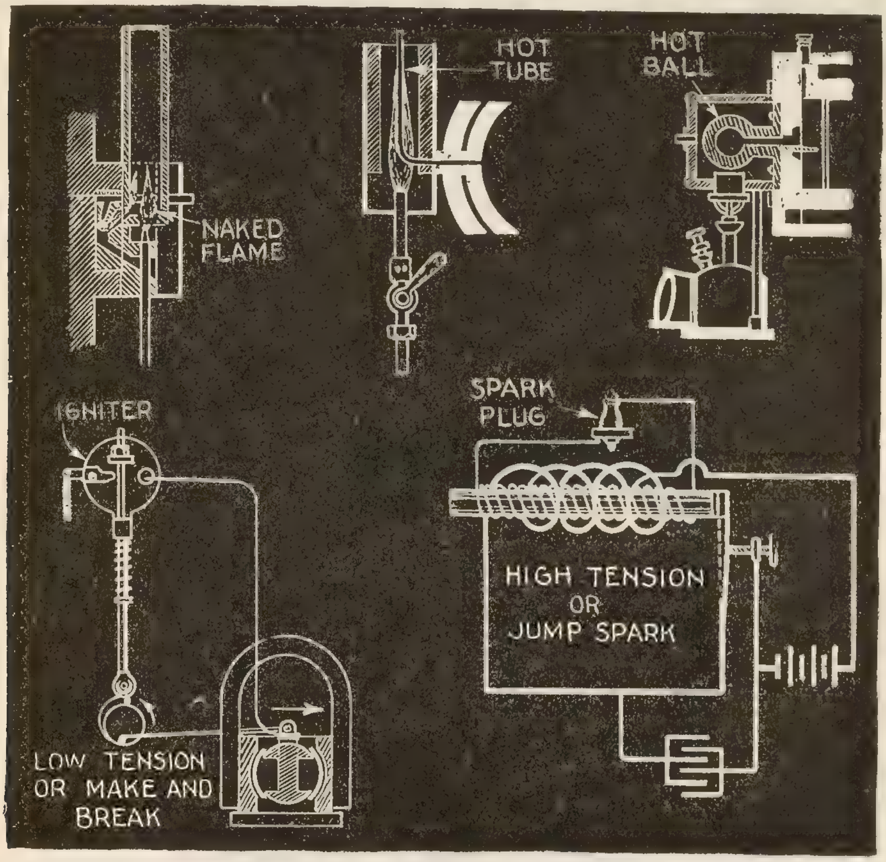


FIG. 10,082.—Stewart vacuum gasoline system, for use where the gasoline tank is lower than the carburetter. The vacuum tank is divided into two chambers, upper and lower. The upper chamber is connected to the inlet manifold while another pipe connects it with the main gasoline supply tank. The lower chamber is connected to the carburetter. The intake strokes of the engine create a vacuum in the upper chamber of the tank, and this vacuum draws gasoline from the supply tank. As the gasoline flows into this upper chamber it raises a float valve. When this float valve reaches a certain height it automatically shuts off the vacuum valve, and opens an atmospheric valve, which lets the gasoline flow down into the lower chamber. The float valve in the upper chamber drops with the gasoline flowing out, and when it reaches a certain point it in turn reopens the vacuum valve, and the process of refilling the upper chamber begins again. The same processes are repeated continuously and absolutely automatically. The lower chamber is always open to the atmosphere, so that gasoline flows to the carburetter, as required, uninterruptedly and at an even pressure.

values vary similarly with the throttle opening, hence the mixture necessary for maximum power at any given speed differs in accordance with the immediate conditions of combustion.



Figs. 10,083 to 10,087.—Various methods of ignition. Fig. 10,083, naked flame; fig. 10,084, hot tube; fig. 10,085, hot ball; fig. 10,086, low tension electric or make and break; fig. 10,087, high tension electric or jump spark.

Ignition.—Electricity is now almost universally used for ignition. The one property of electricity which makes it available for ignition is the fact that whenever its motion is stopped by interposing a resistance, the energy of its flow is converted into heat. In practice this is accomplished in two ways: 1, by suddenly breaking a circuit; 2, by placing in the circuit a permanent *air gap* which the current must jump. In either case, the intense heat caused by the enormous resistance interposed, produces a spark which is utilized to ignite the charge. The

first method is known as the ***make and break*** or *low tension* and the second, the ***jump spark*** or *high tension.*

Low Tension or "Make and Break" Ignition.—In this system there is a device which is known as an *igniter*, placed in the

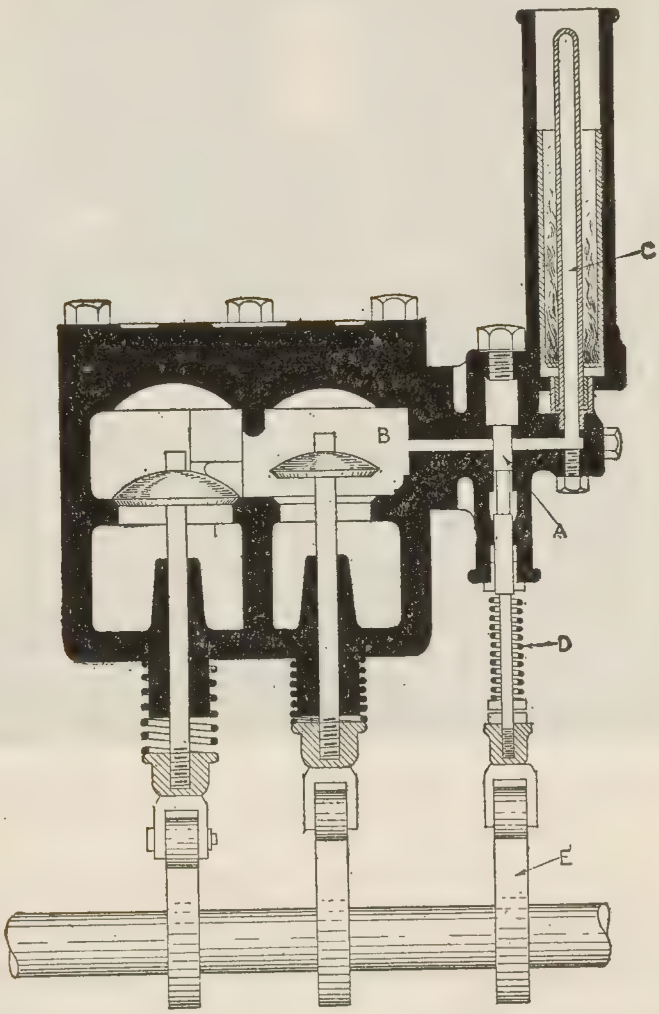


Fig. 10,088.—Sectional view through valves of engine showing hot tube method of ignition. ***In construction,*** a valve A, commonly called the timing valve, is provided, and which is interposed between the admission valve chamber B (communicating with the clearance space of the cylinder), and the interior of the hot tube C. This valve is normally held closed by the spring D. When the piston reaches its inner dead point at the end of the compression stroke, a cam E, on the secondary shaft, opens the valve and allows a portion of the compressed charge to pass into the hot tube where it ignites. The timing valve is held open throughout the power and exhaust strokes, thus permitting the products of combustion to be carried out of the tube with the exhaust.

combustion space of the engine cylinder. This consists of two electrodes, or spark terminals, one of which is stationary and the other movable. The stationary electrode is insulated, while the other having an arm within the cylinder and placed conveniently near is capable of being moved from the outside so that the arm comes into contact with the stationary electrode and separates from the latter with great rapidity. This sudden breaking of the circuit produces an electric arc or

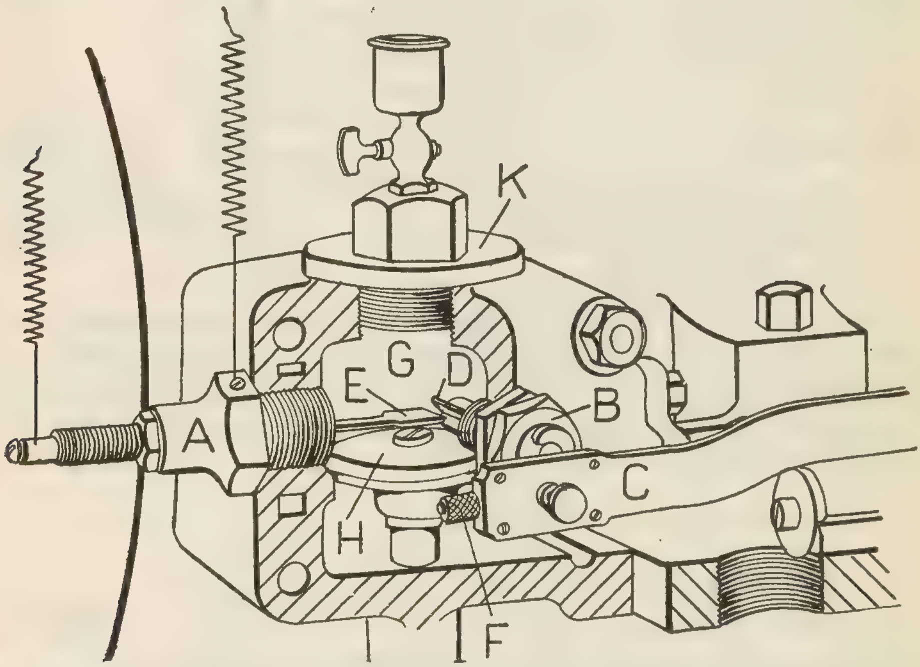


Fig. 10,089.—***Wipe contact*** igniter. It consists of two independent electrodes, the stationary electrode A, and the movable electrode B. When the latter is revolved by the motion of the igniter rod C, the revolving blade D, is brought into contact with the spring E, at each rotation and produces the spark. In this arrangement the break is more effective than in the hammer break type, and gives a larger spark with a given battery capacity, while at the same time, the wiping contact of the two parts prevents the accumulation of burnt carbon or scale on their edges, and thus serves to keep the contact surfaces bright and clean. On the other hand, it possesses the drawbacks incident to the use of a spring which is exposed to the extremely high temperatures developed within the cylinder. The use of flat springs is particularly disadvantageous as it is very difficult to temper them uniformly, and they are consequently liable to break without warning. Furthermore, the wear of the electrodes is excessive. The moment of ignition can be adjusted while the engine is running by turning the thumb screw F, on the end of the igniter rod, and this screw is used also to retard the impulses at starting, thus preventing the engine moving backwards. The igniter is located in the inlet chamber G, directly over the head of the admission valve H, and either one of the electrodes can be reached for inspection or removal, independently, by simply removing the cap K.

primary spark caused by the inductance, that is, by the "inertia" or tendency of the current to continue flowing after the separation of the contact points.

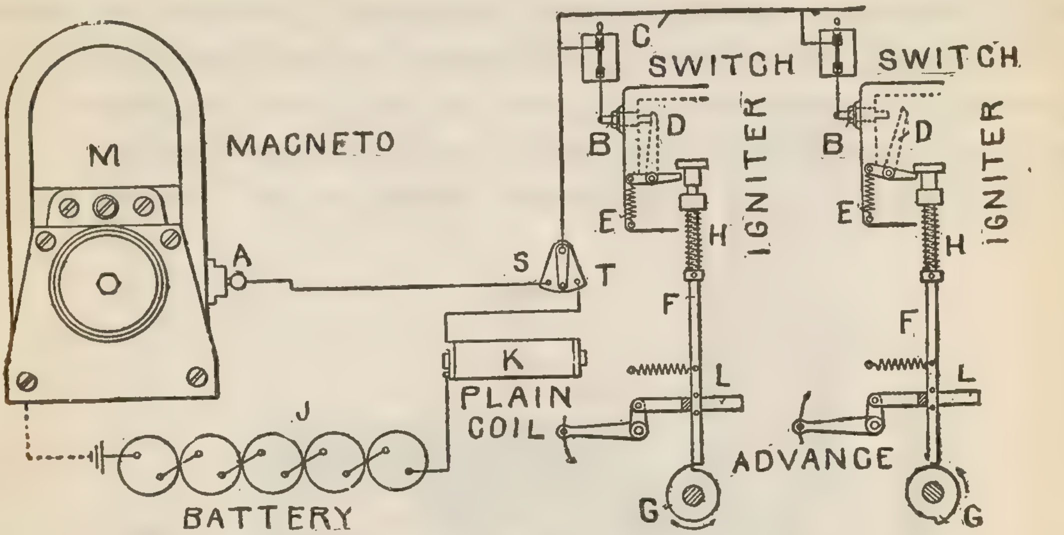
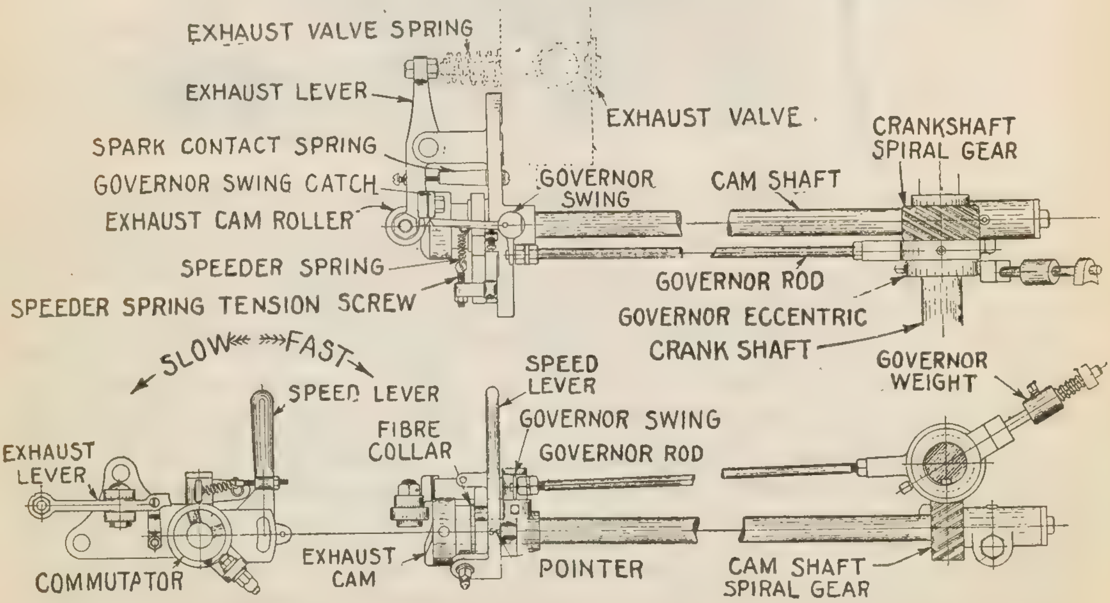


FIG. 10,090.—A low tension or make and break ignition system. ***In operation,*** as the nose of the cam G, passes rod F, the latter suddenly drops by the action of spring H. The lead of the rod, which has been raised by the cam somewhat above the arm of D, will in its descent strike D, a blow which abruptly breaks contact between D and B, thus producing a spark. When not acted upon by the head of the rod F, D, is held in contact with B, by the Spring E. The system is explained in detail in the text.



FIGS. 10,091 to 10,093.—Governor and valve mechanism of Domestic, type F, engine.

The current may be derived from either a primary battery, storage battery or low tension magneto.

In make and break ignition it is necessary in order to produce a good spark, that the "break" or separation of the contact points of the igniter should take place with ***extreme rapidity,*** that is the spring H (fig. 10,090) should be sufficiently strong to cause the

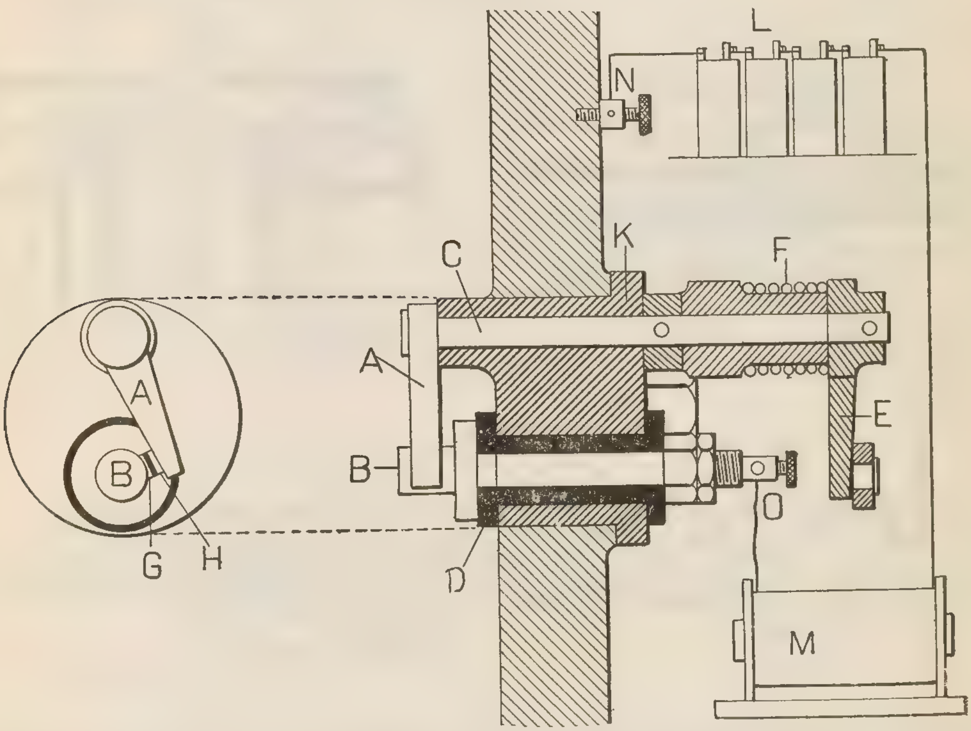


FIG. 10,094.—***Hammer break*** igniter. ***It consists of*** two metallic terminals A and B. The terminal A, is mounted on a movable shaft C, while B is stationary and ***insulated*** from the cylinder wall by the lava bushing D. A suitable cam rod, attached to the crank E, provides the means for rocking the terminal A, so as to bring it in contact with the terminal B, ***and then quickly separate*** the terminals to produce the spark. The helical spring F, provides a semi-flexible connection between the shaft C, and the crank E. The contact points of the two terminals are tipped with two small pieces of platinum G and H, and both terminals are mounted in the removable plug K, which is usually inserted through the wall of the cylinder head, so that the igniter points extend into the compression space of the cylinder. In the circuit is a battery L, and primary spark coil M. ***In operation,*** when the igniter terminals are brought together, the circuit is closed through the battery and the spark coil, and when the terminals are ***quickly separated,*** the self-induction of the coil causes an electric arc between the igniter terminals which ignites the charge.

shoulder or rod F, when it falls, to strike the igniter arm a decided blow, thus quickly snapping apart the contact points.

High Tension or "Jump Spark" Ignition.—In this method of producing a spark, a device called a *spark plug* is employed. This consists of two stationary electrodes, one of which is grounded to the engine cylinder and the other insulated. The points of the electrodes are permanently separated from each other by about $\frac{1}{32}$ of an inch, the space between the points

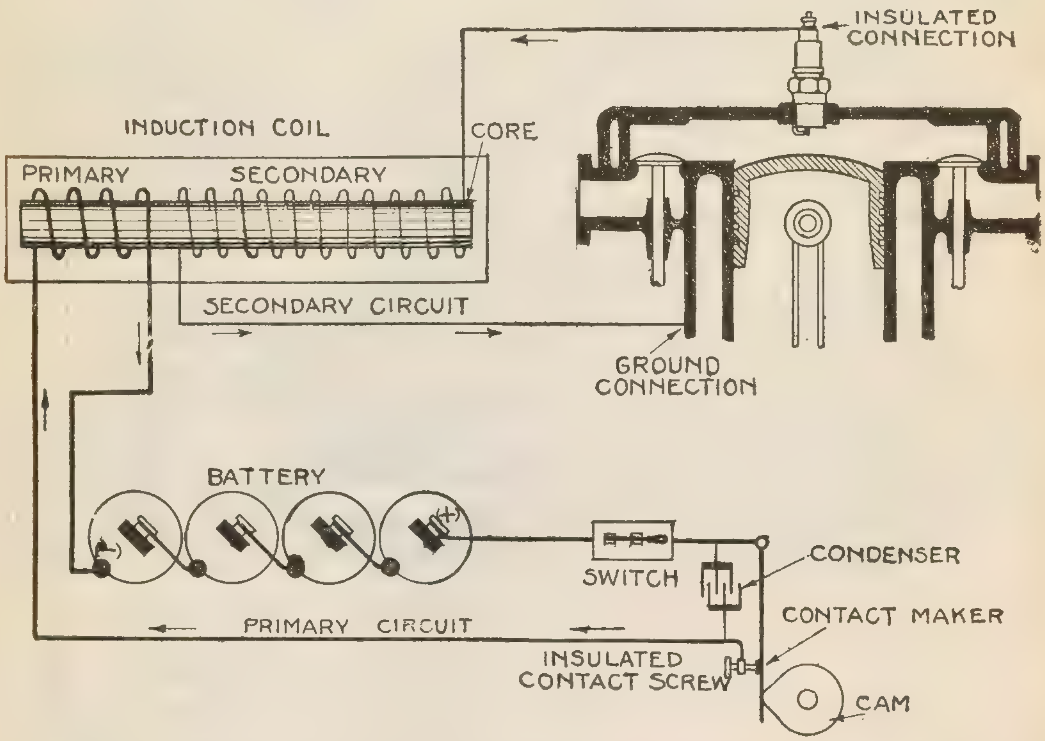


FIG. 10,095.—Diagram illustrating the principles of high tension or jump spark ignition. The nose of the cam in revolving engages the contact maker which completes the primary circuit and allows current to flow from the battery through the primary winding of the coil; this magnetizes the core. The primary circuit is now broken by the action of the cam and magnetic changes take place in the coil which induce a momentary high tension current in the secondary circuit. The great pressure of this current forces it across the air gap of the spark plug and as it bridges the gap a spark is produced. The arrows indicate the paths of the currents.

being known as an *air gap*. This space offers so much resistance to the flow of an electric current that a very high pressure is required to cause the current to burst through the air gap and produce a spark, hence the term "high tension ignition."

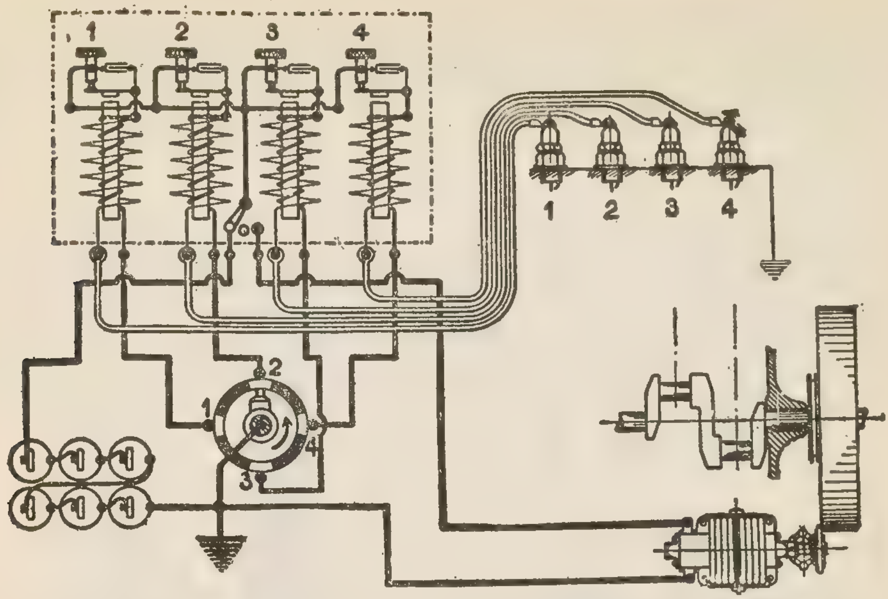


FIG. 10,096.—Wiring diagram of a dual jump spark ignition system for a four cylinder four cycle engine. A dry battery and low tension magneto form the two sources of curent supply. The primary, or low tension circuit is shown by heavy lines, the secondary or high tension circuit by fine lines and the leads to spark plugs by the double lines. The dotted rectangle represents the outline of a four unit dash coil.

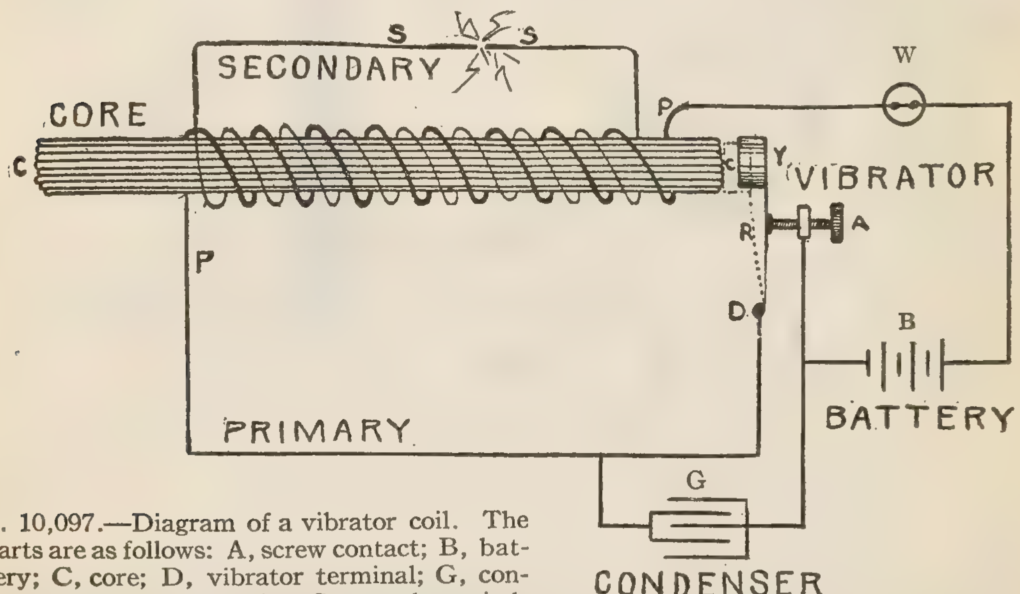


FIG. 10,097.—Diagram of a vibrator coil. The parts are as follows: A, screw contact; B, battery; C, core; D, vibrator terminal; G, condenser; P, primary winding; S, secondary winding; W, switch; Y, vibrator. When the switch is closed, the following cycle of actions takes place; 1, the primary current flows and magnetizes core, 2, magnetized core attracts the vibrator and breaks primary circuit, 3, the magnetism vanished, inducing a momentary high tension current in the secondary winding, 4, magnetic attraction of the core having ceased, vibrator spring re-establishes contact, and 5, primary circuit is again completed and the cycle begins anew.

Since the spark jumps from one electrode to the other, this method of igniting the charge is also known as the *jump spark* system. The spark itself is properly described by the prefix *high tension* or *secondary.*

In the production of the spark two distinct circuits are necessary: 1, a low tension or *primary* circuit, and 2, a high tension or *secondary* circuit.

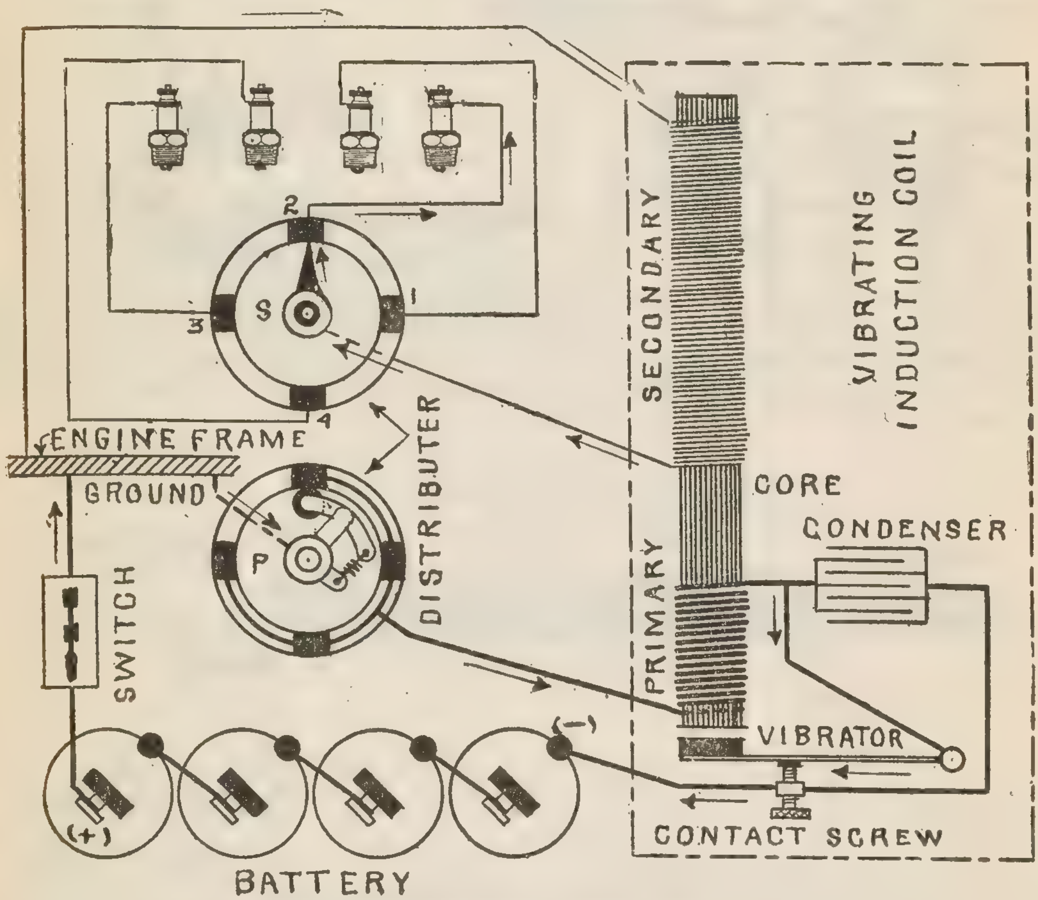


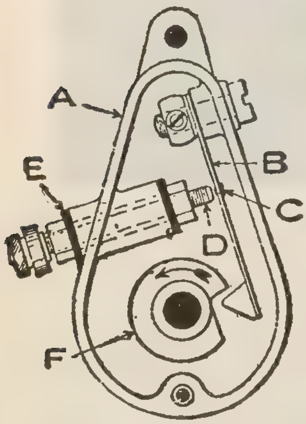
FIG. 10,098.—Diagram illustrating the principles of synchronous ignition. ***For clearance*** the primary and secondary elements of both the coil and the distributer are shown separated When the primary rotor of the distributor completes the primary circuit, current from the battery flows and the vibrator operates, making and breaking the current with great frequency. A high tension current, made up of a series of impulses, is induced in the secondary circuit and distributed by the rotor arm during its revolution to the several cylinders in the proper order of firing.

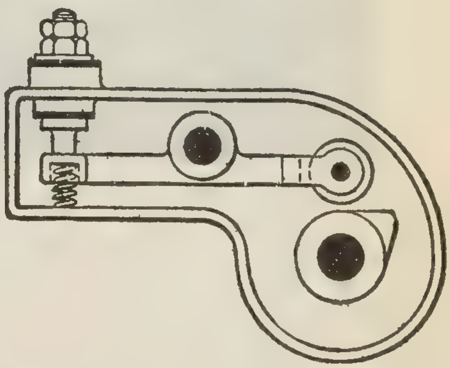
The current which flows through the low tension circuit is called the *primary current*, and that which it *induces* in the high tension circuit, the *secondary current.*

In order to obtain the high pressure required to produce a spark, a device known as a *secondary induction coil* is used which transforms the primary current of low voltage and high amperage into a secondary current of high voltage and low amperage, that is, the quantity of the current is decreased and its pressure increased.

The general principles upon which high tension or jump spark ignition is based are as follows:

An automatic device is placed in the primary circuit which closes and opens it at the time a spark is required. When the circuit is closed, the primary current flows through the primary winding of the coil and causes a secondary current to be induced in the secondary winding. The spark plug being included in the secondary circuit opposes the flow of the current





FIGS. 10,099 and 10,100.—A contact maker and mechanical vibrator or ***trembler.*** The case A, fig. 10,099 is attached to the gear box of the engine; B, is the blade; C, a platinum contact point; D, an insulated adjusting screw; E, a bushing with insulation; F, the operating cam. As this cam revolves, the weight on the end of blade B, drops into the recess on the cam, causing the blade to vibrate and make a number of contacts with D, thus producing a series of sparks when in operation. Fig. 10,100 shows a mechanical vibrator or ***trembler.***

by the high resistance of its air gap. Since the pressure of the secondary current is sufficient to overcome this resistance. it flows or "jumps" across the gap and in so doing intense heat is produced in a spark.

NOTE.—The ***automatic device*** which controls the primary current to produce a spark by the first method is called a *contact maker*, and by the second method, a *contact breaker*. A closed primary circuit w th a contact breaker is used to advantage on small engines run at very high speed as it allows time for the magnetism or magnetic flux in the core of the coil to attain a density sufficient to produce a spark. The word *timer* is usually applied to any device which controls the primary current, when it controls both the primary and secondary currents, as in *synchronous ignition* it is called a *distributer*.

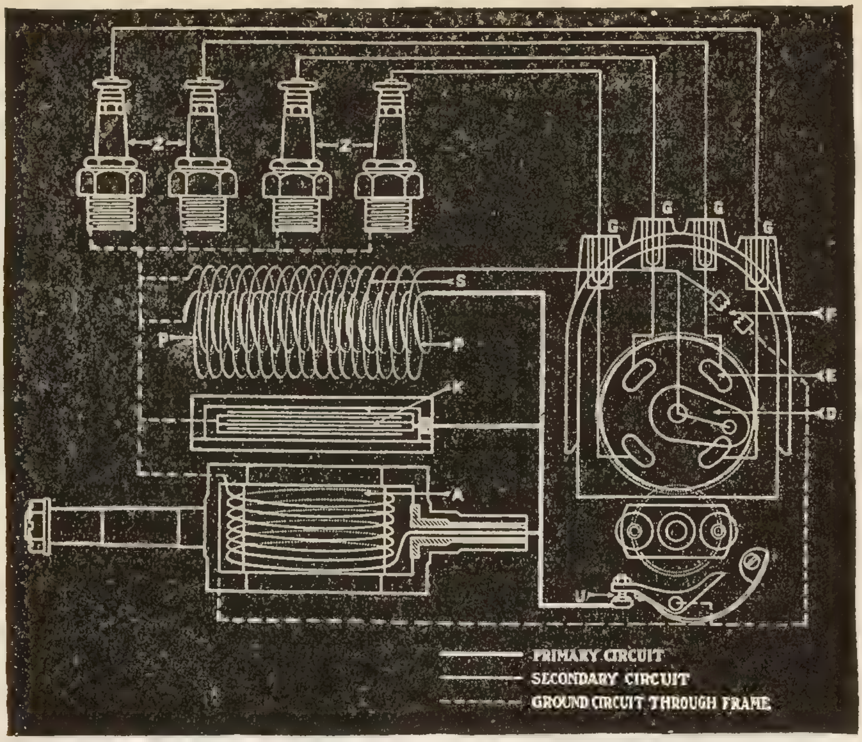


FIG. 10,101.—Circuit diagram of a ***magneto*** with ***self-contained coil.*** A, is the armature winding; P, primary —, S, secondary of transformer; D, distributing brush carrier; E, contact segments; F, safety spark gap; G, terminals to plugs; U, interrupter; Z, spark plugs. ***In operation,*** alternating current flows from the armature having two points of maximum pressure in each armature revolution. As the current leaves the armature, it is offered two paths: 1, the shorter through the interrupter U, to the ground, and 2, the longer through the primary P, of the induction coil to the ground. A third path through the condenser K, is only apparently available; it is obstructed by the refusal of the condenser to permit the passage of the current, as the condenser will merely absorb a certain amount of current at the proper moment, that is at the instant of the opening of the interrupter. The interrupter being closed the greater part of the time, allows the primary current to avail itself of the short path it offers. At the instant at which the greatest current intensity exists in the armature, the interrupter is opened mechanically so that the primary current has no choice but must take the path through the primary P, of the induction coil. A certain amount of current is at this instant also absorbed by the condenser K. This sudden rush of current into the primary P, of the induction coil, induces a high tension current in the secondary winding S, of the coil which has sufficient pressure to bridge the air gap of the spark plug. The sharper the rush of current into the primary winding P, the more easily will the necessary intensity of current for a jump spark be induced in the secondary winding S. ***The distribution of the current*** in proper sequence to the various engine cylinders is accomplished as follows: the high tension current induced in the secondary S, of the induction coil is delivered to a distributing brush carrier D, that rotates in the magneto at half the speed of the crank shaft of the engine. This brush carrier slides over insulated metal segments E, there being one for each cylinder. Each of these segments E, connects with one of the terminal sockets that are connected by cable with the spark plugs as shown. ***At the instant of interruption*** of the primary current, the distributing brush is in contact with one of the metal segments E, and so completes a circuit to that spark plug connected with this segment. Should the circuit between the terminal G, and its spark plug be broken, or the resistance of the spark plug be too great to permit a spark to jump, then the current might rise to an intensity sufficient to destroy the induction coil. To prevent this what is known as a safety spark gap is introduced. This will allow the current to rise only to a certain maximum, after which discharges will take place through this gap. ***In construction,*** the spark discharges over this gap are visible through a small glass window conveniently located.

Sometimes the spark is obtained by keeping the primary circuit closed except during the brief interval necessary for the passage of the spark at the plug points. A secondary spark, then, may be produced by either open or closed circuit working, that is, the primary circuit may be kept either opened or closed during the intervals between sparks.

Cooling Systems.—As the cylinder of a gas engine is an explosion chamber, that is, a furnace wherein the fuel is burned, and the explosions are very frequent, it is necessary to adopt some means to cool the cylinder walls. If the cylinder

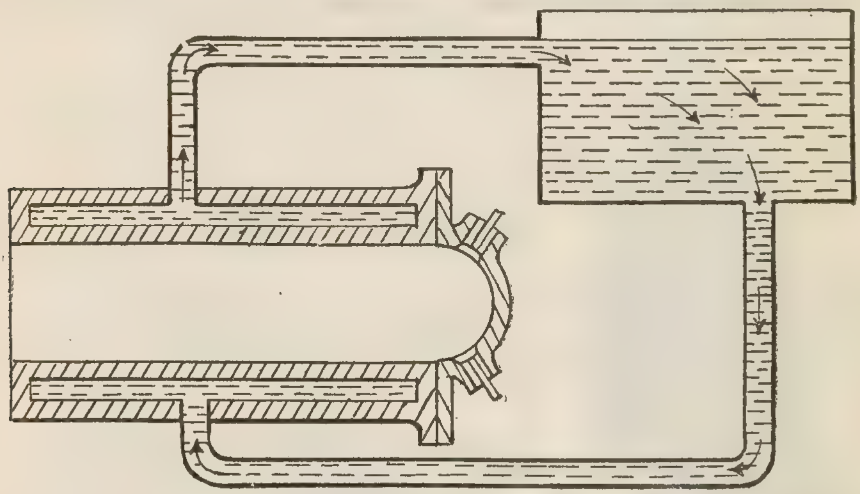


FIG. 10,102.—Diagram of a gravity water circulation system for a gas engine cylinder. As indicated by the arrows, the water from the tank enters the jacket of the cylinder at the lowest point, and being there subjected to the heat of the cylinder walls, rises to the level of the tank water; thus maintaining a continuous circulation.

were not cooled in some way, it would get red hot, lubrication under such conditions would be impossible, and the casting would be destroyed in a short time.

In addition, the temper would be taken out of the valve springs, the spark plugs would possibly crack, and the incoming charge become so rarefied as to seriously impair the power of the engine.

Although a cooling system is a necessity, for the reasons stated above, it always causes a loss by absorbing a part of

the heat units generated by the combustion of the fuel, thus reducing the efficiency of the engine.

The two methods used to cool the cylinder are

1. A jacket of circulating water;
2. Induced air currents.

In the first method a thin space around the cylinder is provided for the water by an outer casing of metal, either cast with the cylinder, or attached as in the case of a sheet copper casing.

The cooling or *circulating water*, after passing through the jacket and absorbing heat from the cylinder, passes off to 1, a tank 2, radiator (in the

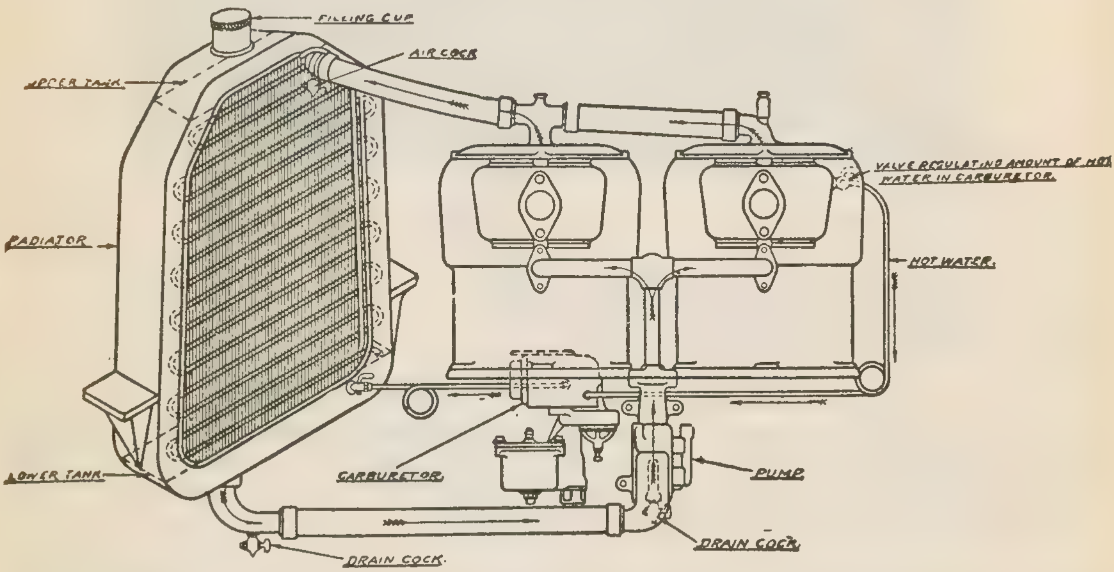
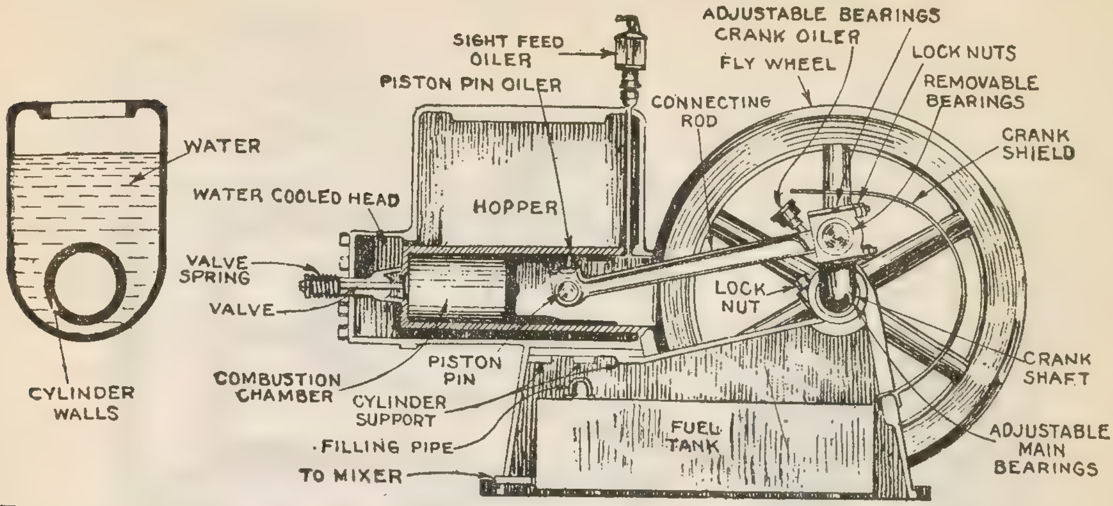


Fig. 10,103.—An example of a radiator and water cooling system with pump circulation. The cooling is assisted by a fan geared to the engine which induces a current of air through the radiator when the car is standing.

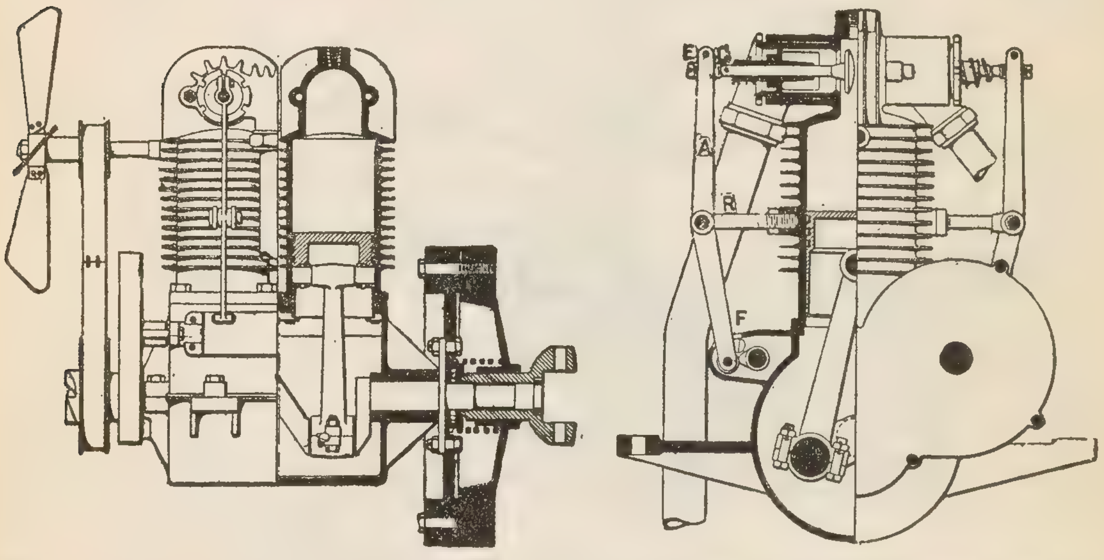
case of an automobile), or 3, to waste. In the first two cases the water is used over and over again.

Since the heat causes the water to evaporate, and in some cases, to boil, it must be replenished from time to time where a tank or radiator is used.

In tank or radiator systems the water is kept in circulation



Figs. 10,104 and 10,105.—Sectional views of Fuller and Johnson gas engine cylinder showing open jacket or "hopper" method of cooling. The hopper consists of a large vessel surrounding the cylinder, which holds a sufficient quantity of water to adequately cool the cylinder. The water circulation is by gravity.



Figs. 10,106 and 10,107.—An air cooled engine. The fan shown at the left induces a current of air which passing over the large surface presented by numerous ribs, cools the cylinders. The valves are located above the cylinder bore in opposite chambers and work horizontally. Each valve is operated by a long vertical lever A, pivoted at R. The upper end C, bears upon the end of the valve stem and its lower end carries a roller against which bears the camshaft cam D. The upper end of the lever or valve rocker arm is split and takes a threaded piece E, which rests upon the end of the valve stem. By the adjustment of this the timing of the valve is accomplished. The lower end, with its roller is contained within a small extension on a detachable plate secured to the side of the crank case and the end of the valve rocker arm working in a slot F, in the top of the expansion.

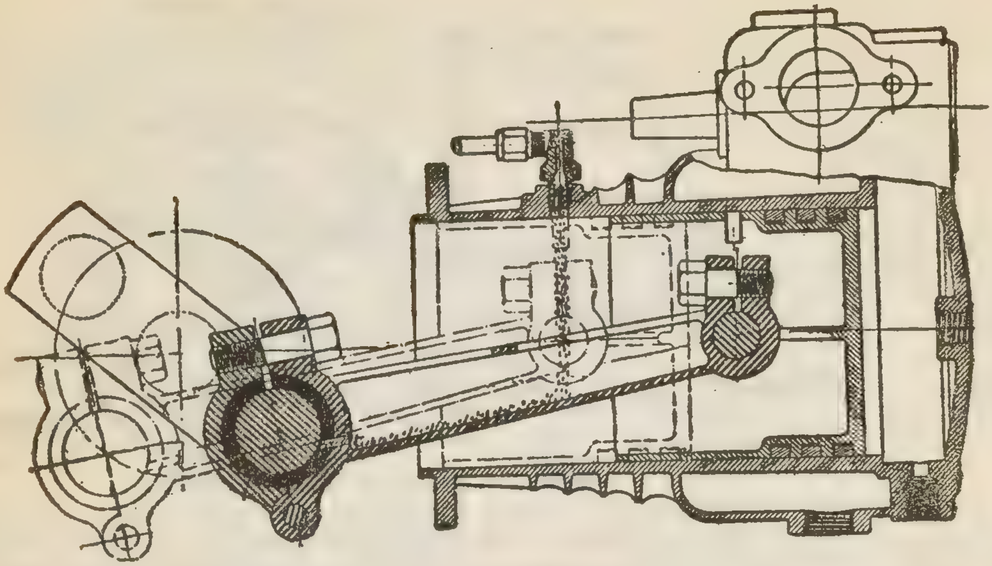


FIG. 10,108.—Horizontal cylinder oiled by force feed oiler distributor. The piston is oiled when passing under oil port, as shown by the dotted outline. The connecting rod is longitudinally grooved on the upper surface, so as to carry oil to the bearings.

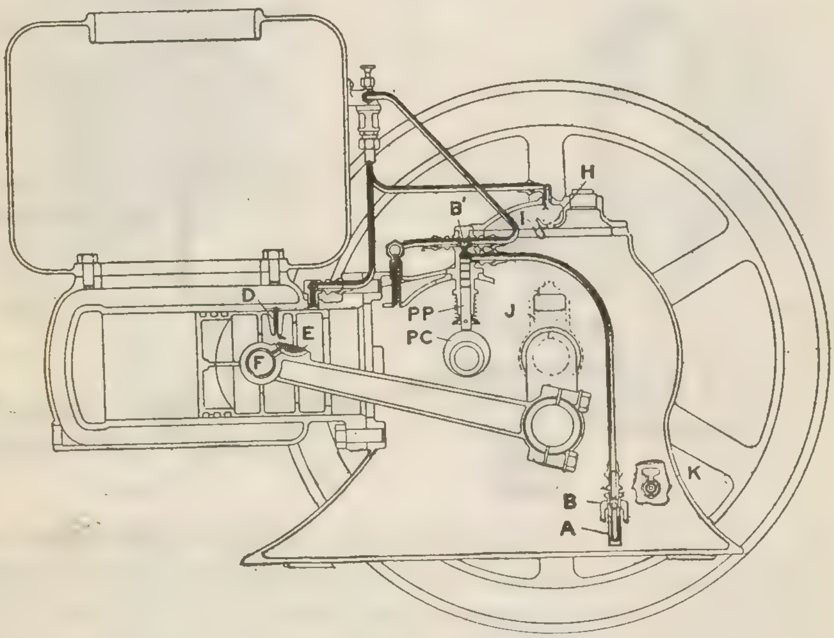
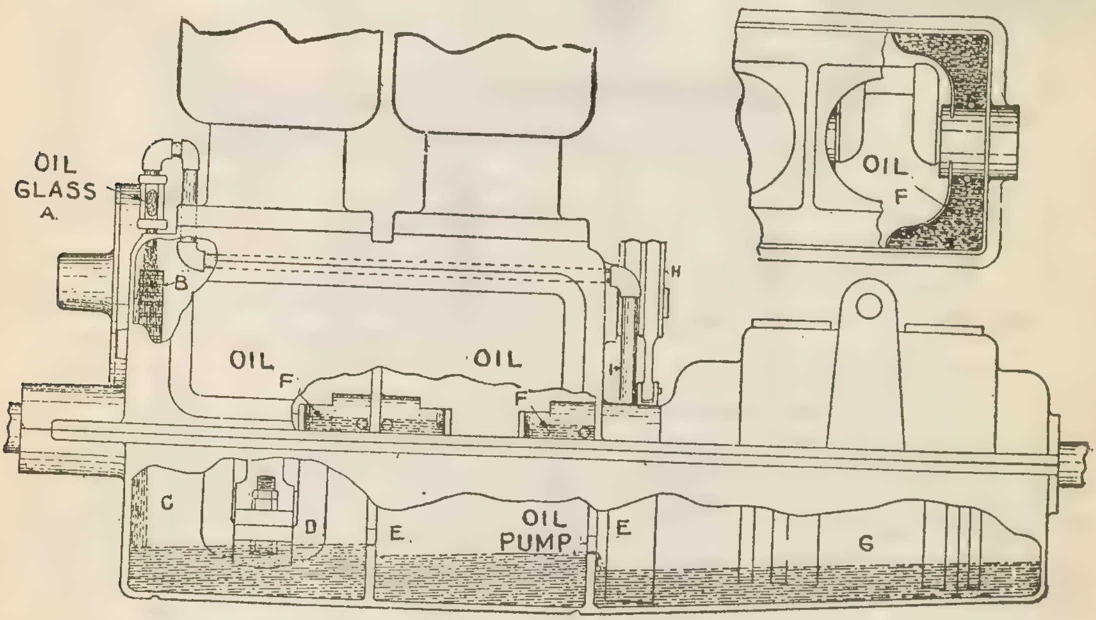


FIG. 10,109.—Gray engine lubrication system. The oil is poured into the reservoir in the bottom of the engine through the cap opening H, in the top of the crank case. The pump PP, forces oil to all working surfaces after drawing it through the strainer A, at bottom of base. A large pocket J, is located directly over each crank shaft bearing (these pockets can be seen by looking at the outside of the engine) and catches oil from the feed pipe and keeps the main bearings bathed in oil at all times.

1. Gravity, or
2. Mechanical means.

Lubrication Systems.—There are several methods of gas engine lubrication in general use, and they are known as gravity, splash, pressure, and positive systems.

1. In the ***gravity system***, the lubricator is placed at a sufficiently high elevation to permit the oil to flow to the bearings;



FIGS. 10,110 and 10,111.—Palmer marine engine lubrication system. The pump forces oil from the base reservoir through the pipe I, and oil glass A, falling over gears B, and forward crank bearings. At C, oil is shown dropping from gears and crank bearings to the forward compartment, oiling crank pin bearing D, and splashing by throw of connecting rod to cylinder walls and wrist pin. The centrifugal motion of the horizontal gears throws the oil that drips off the large cam gear into the cam bearing. The opposite forward cam shaft bearing has a recess to catch the oil, supplying the bearings. Partition plates and oil passages maintain a uniform level of the oil. The circulation is continuous.

2. In the ***splash system***, a quantity of oil is placed in the crank case and maintained at such a level that the ends of the connecting rods come in contact with the oil at the lower part of their revolution and splash it upon the working parts;

3. In the ***pressure system***, the oil is contained in a reservoir and forced to the various bearings under pressure acquired by

connecting the reservoir to the exhaust by a small pipe, or by utilizing the pressure from an enclosed crank case; in the ***positive system***, a pump geared to the engine forces a certain amount of oil through the feed at each stroke of the plunger.

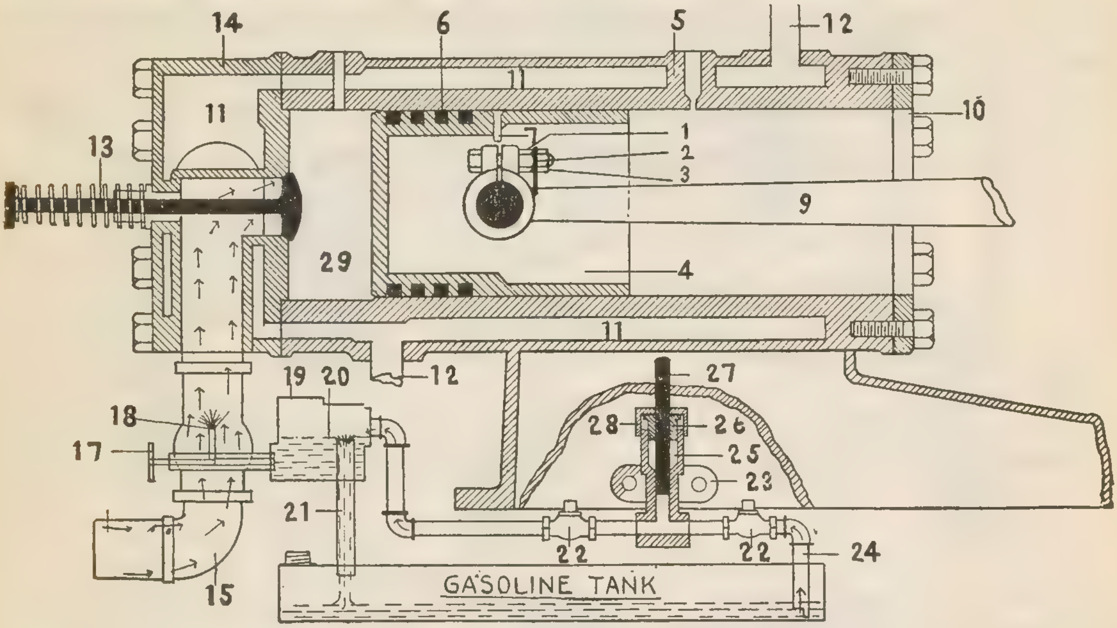


FIG. 10,112.—Sectional view of Gilson four cycle gasoline engine cylinder. ***The parts are:*** 1, adjusting nut; 2, lock washers; 3, jam nuts; 4, piston; 5, cylinder; 6, piston rings; 7, piston bearing oil tube; 8, piston bearing; 9, connecting rod; 10, cylinder packing ring; 11, water jackets; 12, water inlet and outlet; 13, intake valve; 14, cylinder head; 15, intake pipe; 16, gasoline needle valve; 17, gasoline feed pipe; 18, gasoline reservoir; 19, gasoline level; 20, overflow pipe; 21, check valves; 22, gasoline pump; 23, gasoline suction pipe; 24, pump packing; 25, packing gland; 26, pump; plunger; 27, packing gland regulating nut.

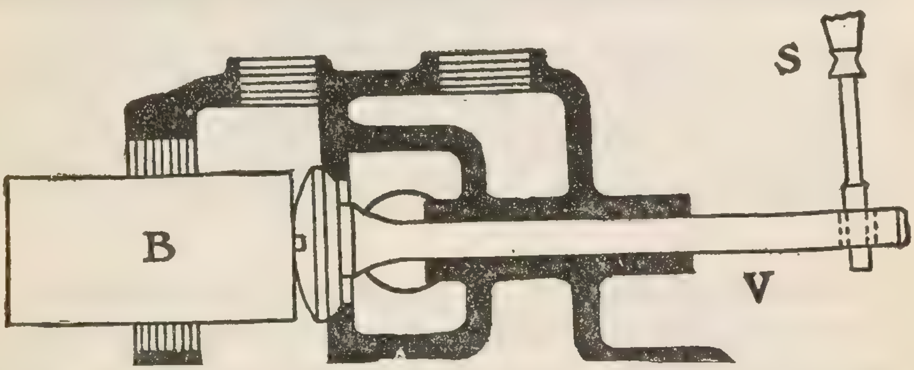


FIG. 10,113.—Method of grinding valves in horizontal cylinders. A block of steel B, is held against the head of the valve V, and the latter rotated on its seat by means of a screw driver blade S, inserted in the slot in the stem, the face having been previously trued by a truing tool. In cases where the stem of the valve has no slot, a pair of gas pliers can be used to grip it, being careful in so doing not to mutilate the threads thereon. The valve may be turned by a piece of steel wire inserted in the pin hole.

TROUBLE CHART FOR GASOLINE ENGINES

1. TROUBLES IN STARTING

(From Report by G. E. P. Smith, University of Arizona, Agricultural Experiment Station)

First, Turn Engine Slowly Through a Full Cycle and Note the Occurrence of Events

I. Ignition	1. (*a*) Battery	Test cells for amperage. (Reject a cell when below six amperes) Test storage batteries for voltage
	(*b*) Magneto	Poor contact of brushes Commutator smeared with oil Driven too slowly
	2 (For all engines)	Electric circuit not complete Poor contacts in wiring or in switch Wiring incorrect or short circuiting
	3. (*a*) Make-and-break Mechanism	Igniter mechanism out of time Igniter points roughened. (Use file or small hammer) Igniter points making poor contact on account of carbon deposit Igniter points short circuited by soot or oil, causing poor break Weak spring, causing slow break Insulation of stationary electrode broken
	(*b*) Jump-spark equipment	Induction coil vibrator stuck or out of adjustment Spark out of time Spark points short circuited by oil or carbon soot Spark points too far apart. Distance should be 1/32 inch or a little less Spark plug cracked and short-circuiting
II. Carbureter	1. Lack of gasoline	Tank empty Needle valve insufficiently open Inlet passages clogged Gasoline pump out of order Water accumulated in gasoline tank or in mixer
	2. Incorrect mixture of air and gasoline	Too rich Too weak (Prime it, but not too freely)
III. Engine	1. Cold Cylinder	
	2. Inlet or exhaust valve out of time	
	3. Very poor compression	Exhaust or intake valve does not close Piston rings much worn Cylinder gaskets blown out

2. TROUBLES AFTER STARTING

I. Misfiring	1. Ignition	Weak run-down batteries Poor connections Foul igniter points (or spark plugs)
	2. Carburetor	Lean mixture Gasoline tank nearly empty Fuel pump needs repacking Water in gasoline
	3. Motor	Cold cylinder Very poor compressions
II. Pounding	1. Spark too early	Should occur at from 10 to 20 degrees before dead center,
	2. Pre-ignition	Cylinder overheated Red hot carbon deposit in cylinder
	3. Looseness	Connecting rod bearings Main shaft bearings Fly wheel
	4. Hot Bearings	
	5. Tight Piston	No circulating water Cold water added suddenly when cylinder is hot may be the cause

TROUBLES AFTER STARTING—*Continued*

III. Back-firing	1. Late ignition	
	2. Weak mixture	
	3. Glowing points in cylinder	
	4. Inlet valve	Leaky Weak spring
IV. Explosions in Exhaust Pipe	1. Weak or irregular ignition	
	2. Weak mixture	
V. Over-heating	1. In cylinder	Late ignition Mixture too rich Insufficient lubricating oil Insufficient cooling water Impeded circulation of cooling water Poor compression
	2. In bearings	Lack of oil Screwed down too tightly
VI. Loss of Power	1. Ignition	Too late. (Advance it almost to where it causes pounding) Foul igniters (or spark plugs)
	2. Carburetor	Gasoline used up Passages partially clogged Needle and air valves must be set for running conditions Inlet valve does not lift sufficiently, because of wear
	3. Overheating	In cylinder In bearings
	4. Leaky compression	Valves do not close properly, springs gummy or weak, stems bent, valves or valve seats worn or pitted Piston rings gummy and sticking Piston rings and cylinder worn and out of circular shape Cylinder gaskets leaking
	5. Exhaust pipe	Gummy and partially clogged
	6. Engine overloaded	
VII. Smoke	1. Black smoke in exhaust	Mixture too rich
	2. Light bluish smoke in exhaust	Too much lubricating oil
	3. Escaping past the piston	Worn or stuck rings
VII. Irregular Speed	1. Irregular ignition	Weak batteries Loose electric contacts Worn make-and-break mechanism
	2. Irregular fuel supply	Fuel pump needs repacking
	3. Valves	Weak springs
	4. Governor	Stuck up with gummy oil and dirt, or with paint Out of adjustment Worn loose Needs lubrication

CHAPTER 155

Oil Engines

The constantly increasing cost of gasoline has caused an insistent demand for engines that can operate on cheaper fuels, such as kerosene, heavy oils, etc. This demand has in turn caused manufacturers to give serious attention to the subject and many of the difficulties encountered have been overcome.

Classification of Oil Engines.—Numerous types of oil engines have been developed in order to utilize the various grades of fuel oil, each type possessing certain features adapting it to the use of a certain grade or grades of oil.

In general the simplicity and cost of the engine varies inversely with the grade of the oil, in other words, the simpler the engine, the higher the grade of oil required; the more elaborate and bulky the engine, the lower the grade of oil which may be successfully used.

Oil engines may be classed:

1. With respect to the density of the oil, as:

a. Light oil { kerosene; distillate;

b. Heavy oil { crude oil; fuel oil; tar oil.

2. With respect to method of fuel supply, as:

a. Carburetter;

b. Pump;

c. Pump and compressed air.

3. With respect to ignition, as by

a. Electric spark;

b. Heated metal (vaporizer);

c. Heat of compression.

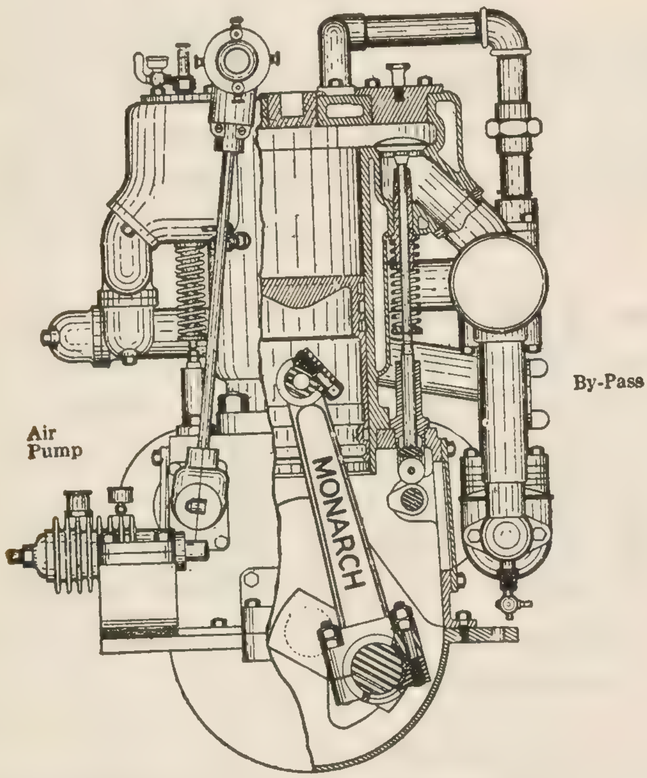


FIG. 10,114.—Sectional view of Monarch marine multiple fuel (gasoline, kerosene) engine showing by pass valve as described in fig. 10,115. Single fuel engine section would be the same except the inlet and exhaust manifold pipes would be different.

4. With respect to the operating cycle:

a. Two (stroke) cycle;

b. Four (stroke) cycle;

c. Low compression { steam scavenging, pump injection;

d. Medium compression { combined pump and air injection or ***semi-Diesel.***

e. High compression: ***Diesel.***

Kerosene Engine.—Kerosene is more difficult to vaporize than gasoline, hence in design special provision must be made to overcome the difficulty.

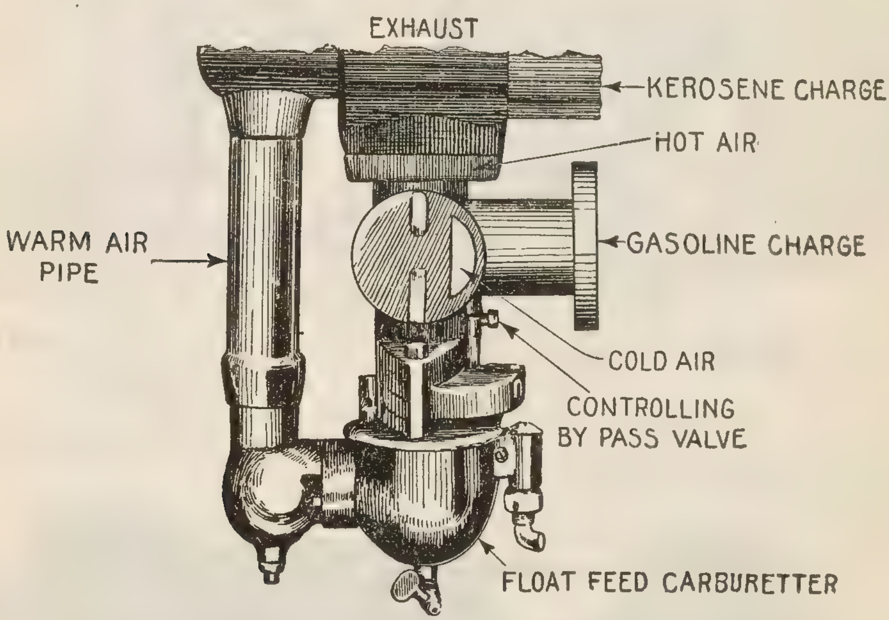


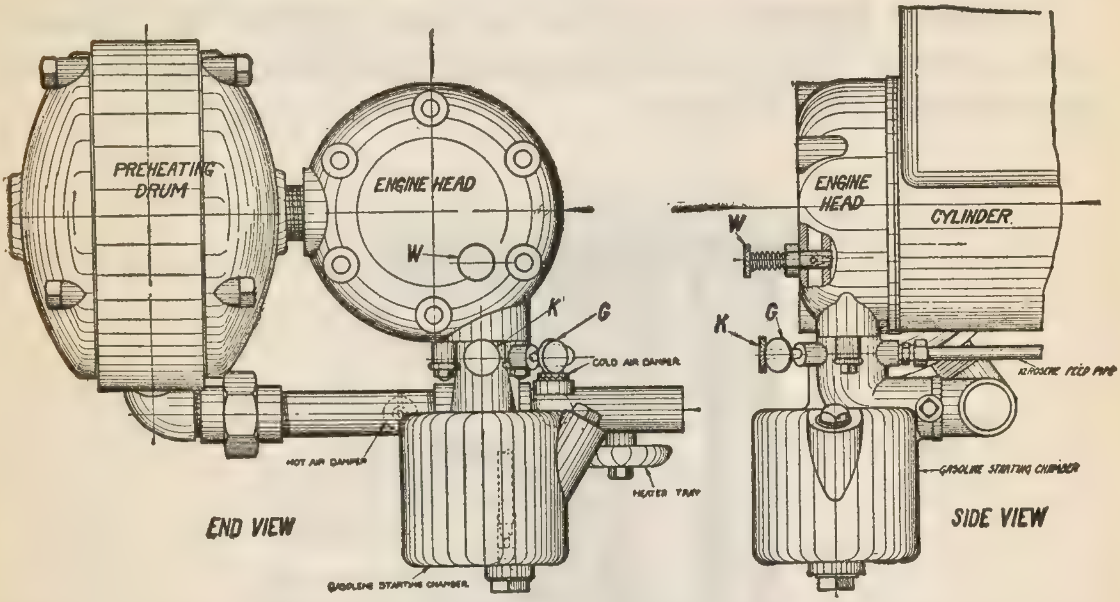
FIG. 10,115.—Monrach by pass as used on Monarch marine multiple fuel engine. This three-way valve is placed above the carburetter as shown and directs charge when placed horizontally, through cold air or lower pipe for gasoline, or when set vertically through annular space around hot exhaust pipe, super-heating and gasifying it for kerosene. Charge temperature may be regulated by adjusting angle of by pass valve.

The term kerosene engines is used to denote the type whose operation *depends on pre-heating* the fuel for the mixture as distinguished from the heavy fuel types in which *the fuel is injected into the cylinder by means of a pump.*

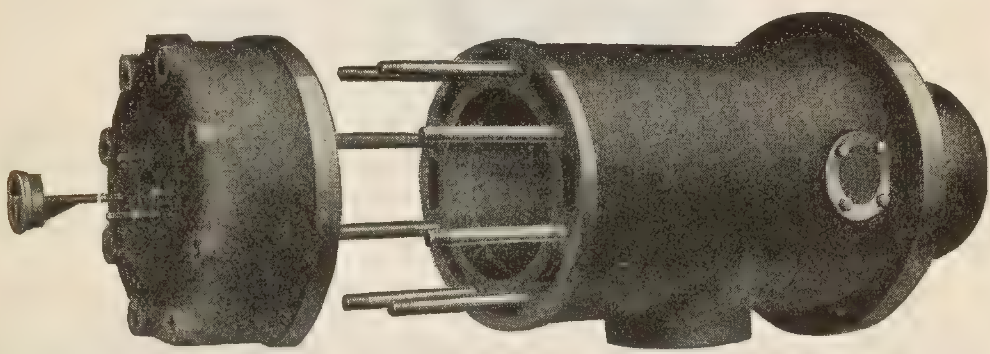
Engines of the latter class however will operate on kerosene and are frequently used with that grade of oil.

Figs. 10,116 and 10,117 show a kerosene engine designed to operate on a pre-heated mixture. As will be seen there is a carburetter or mixer and a heater.

The mixer is provided with two fuel nozzles and a water nozzle. The engine is started on gasoline and run on kerosene after the parts have become sufficiently heated.



Figs. 10,116 and 10,117.—End and side views of R. & V. Triumph kerosene engine showing pre-heating drum, starting chamber, etc.



Figs. 10,118 to 10,120.—Muncie igniter head, igniter spoon, and cylinder disassembled showing construction. The igniter spoon is hollow, having a flat surface on forward end and flange on rear. It is passed through the opening in cylinder head. Over this is placed the igniter head, which has a larger flange that is secured to the cylinder head by means of studs, thus holding the spoon firmly in place. Between the joint to make it tight and hold the compression is placed a copper asbestos gasket. In this manner there is made a complete passage from the cylinder, the combustion chamber, through the spoon and into the igniter head. Over the igniter head is placed a cast iron hood, lined with asbestos to hold the heat in the igniter head.

The water nozzle is used to introduce water into the mixture to prevent excessive temperature on heavy loads and to furnish by dissociation additional oxygen for combustion.

Kerosene engines should preferably be of throttling governor type in order to insure adequate pre-heating because this is not so well maintained in the hit and miss type, especially on light loads.

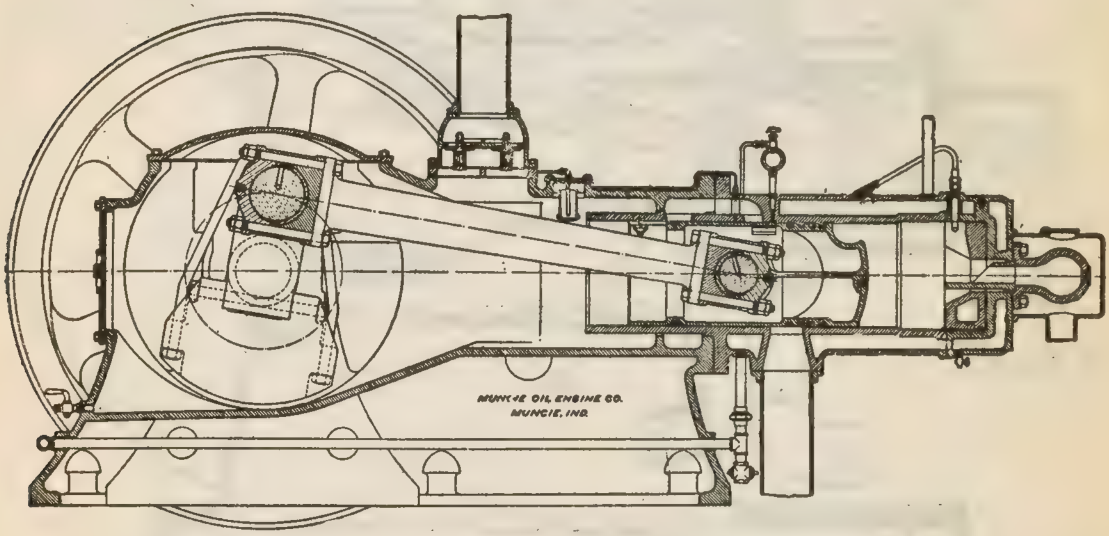


FIG. 10,121.—Muncie low compression two cycle steam scavenger engine. ***The steam*** for the explosive mixture is taken into the combustion chamber in the form of water spray at the same time as the air. It is admitted by means of an adjustable valve on top of cylinder, called the bleeder valve. This water entering the combustion chamber and changing to steam while the exhaust port is yet open assists the incoming air to more thoroughly sweep out the burned gases. The fuel is not put into the combustion chamber until both ports have been closed and the air and steam have been partly compressed at which time it is forcibly injected into the hot compressed air and steam, onto red hot cast iron vaporizing surfaces inside of the combustion chamber, which surfaces are kept incandescent by the explosions. The heat caused by compressing the air, plus the heat absorbed from the hot surfaces inside, assisted by red hot cast iron for any liquid globules to fall onto, issufficient to gasify any oil as soon as injected into the combustion chamber. The red hot surfaces, in addition to assisting in making gas out of the oil for the mixture, also automatically ignite the charge. The governor controls the speed by regulating the length of the fuel injection pump stroke, thus varying the richness of the mixture.

Low and Medium Compression Heavy Oil Engines.—For perfect combustion of heavy oils, the following are the essential conditions:

1. An abundance of oxygen;

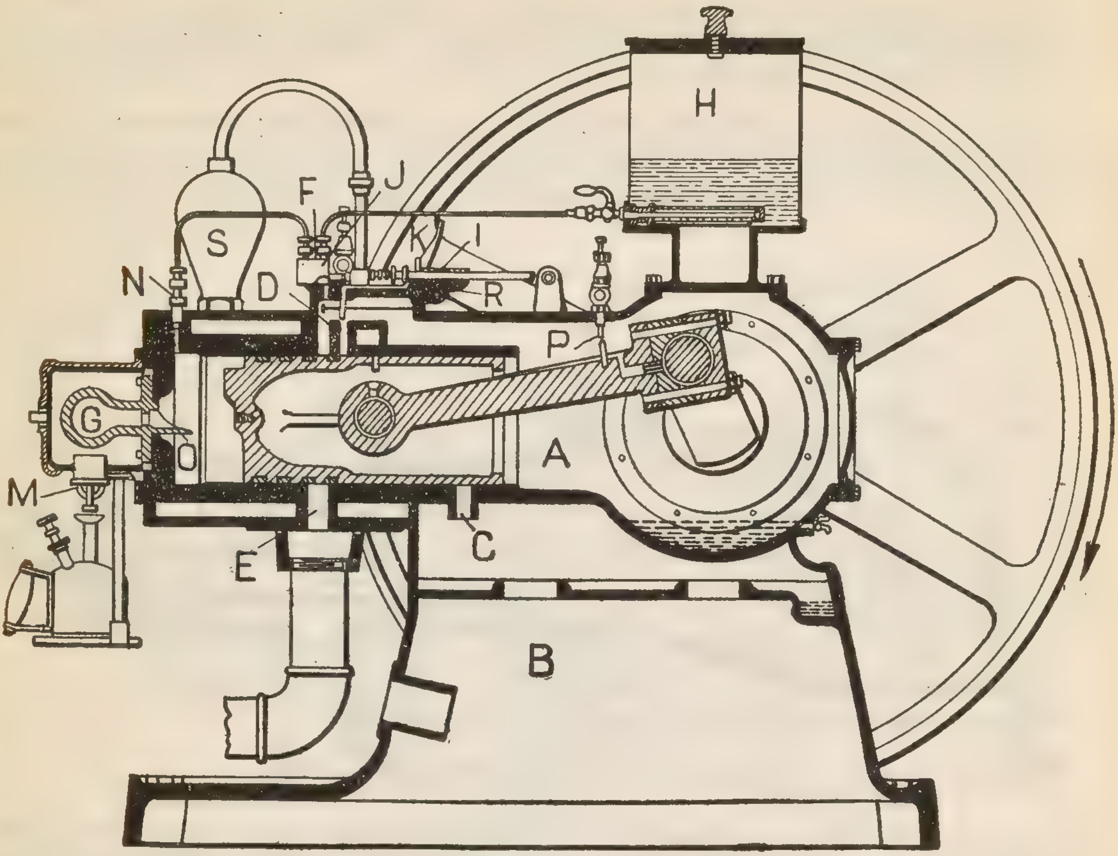


FIG. 10,122.—Meitz and Weiss low compression two cycle steam scavenging engine. ***In operation,*** air is drawn into the closed crank chamber A, from the interior of the base B, through the port C, in the lower part of the cylinder. On the outstroke of the piston, this air is compressed, and the opening of a port D, by the piston, allows the air, together with the steam generated in the water jacket, to pass into the combustion space of the cylinder. At the same time, the exhaust port E, having been overrun, and thus opened by the piston, discharges the products of combustion of the previous charge into the exhaust pipe. The fuel is injected into the cylinder by the pump F, and mixes with the air and steam previously admitted from the crank chamber, so that on the instroke, or compression stroke proper of the piston, the charge is automatically ignited by contact with the heated walls of the igniter ball G. Oil storage tanks capable of holding more than a barrel are placed underground and the engine provided with a small pump to supply the reservoir H. In most cases, the suction pipe of the injector pump F, can be connected directly to the storage tank, or to a small tank placed on the floor or on the engine. The oil pump is of the single acting plunger type, the suction and pressure checks being screwed into the pump body. A small lever serves to operate it by hand in starting the engine, and to draw the oil in case the pipes are not completely filled. During continuous running, it is operated by a rocker arm connected to the eccentric through the plunger guide I. The spring around the plunger L, forces it back to the short spring stop of the guide. ***To stop the engine,*** the pump lever is pulled back while a pressure is exerted on the small projecting pin K, at the side to lock the plunger guide out of action. ***Ignition*** is effected by means of a hollow cast iron ball G, located in the projection attached to the cylinder head. A charge is formed at every revolution of the crank shaft and compressed by the piston into the compression space of the cylinder and the interior of the igniter ball, where it is promptly ignited when the piston reaches

2. Perfect atomization of the fuel, so as to expose a large surface of the oil to the action of the oxygen;

3. Efficient distribution of the atomized fuel with the air charge;

In operation oil is sprayed into the vaporizer immediately after the completion of the exhaust stroke at the same time that the oil is vaporized by the hot walls of the combustion chamber.

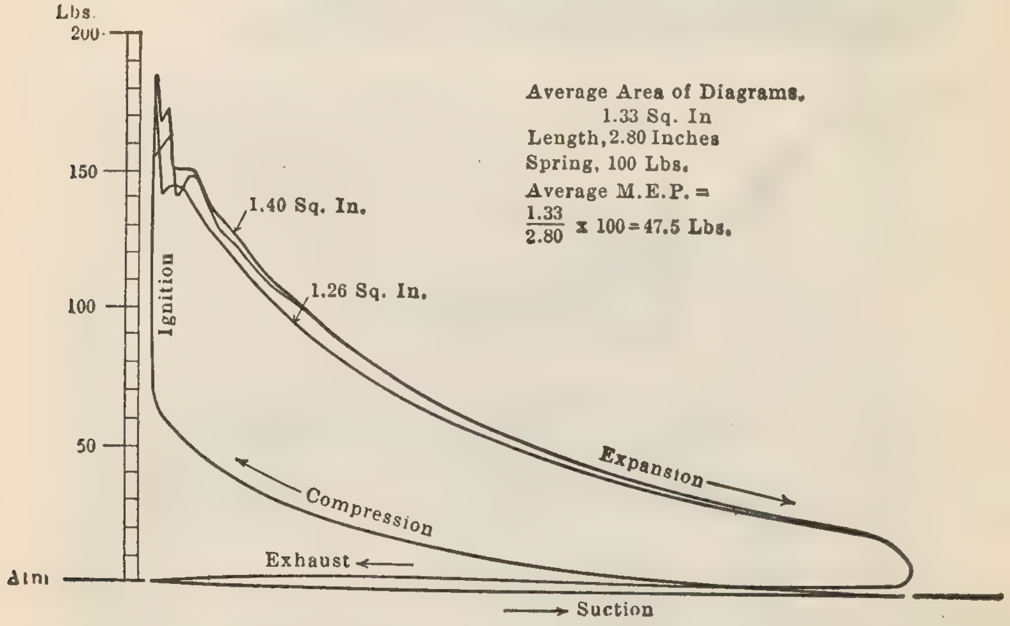


FIG. 10,123.—Indicator diagram of the De La Vergne (type HA) low compression four cycle pump injection heavy oil engine.

On the return stroke, the air is forced into the combustion chamber, and, mixing with the oil vapor, is compressed with it, being ignited at the end of the stroke. The vaporizer here mentioned may be called an *internal* vaporizer as distinguished from an *external* vaporizer or preheater as used on kerosene engines.

FIG. 10,123.—*Text continued.*

the dead point. ***Before starting,*** the igniter ball is heated for a few minutes by a small oil burner, M. The oil jet from the injection nozzle, N, strikes the projection O, extending from the igniter ball and is sprayed, vaporized and mixed with the air and steam in the compression space. The igniter ball is maintained at a dull red heat by the heat of the explosions. The cylinder is water jacketed.

In the four cycle type of heavy oil engine the essential requirements just mentioned are fulfilled as follows:

Suction Stroke.—Admission of a full charge of air into the vaporizer and cylinder.

Compression Stroke.—Compression of the air charge to 150 lbs.

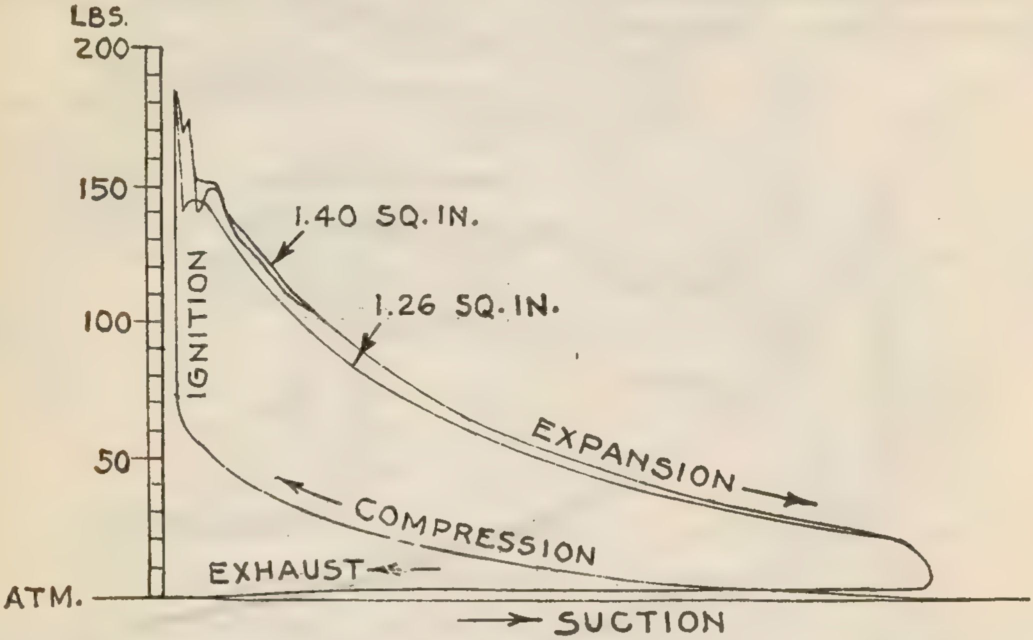


FIG. 10,124.—Typical full load indicator card of De La Vergne (type HA) low compression four cycle pump injection heavy oil engine.

NOTE—***One of the main difficulties*** encountered in the use of external vaporizers or mixture pre-heaters in oil engines is due to the fact, that, the process of vaporization requires the raising of the temperature of the oil vapor and the air with which it is mixed to a temperature ranging from 250° to 300° Fahr., at atmospheric pressure. As a result, the specific gravity of the charge is greatly reduced, so that a given volume contains a less number of thermal units than when it is at atmospheric temperature, and furthermore, the consequent higher initial temperature results in a higher compression temperature for a given pressure than that attained in the case of a gas engine. The total result is a higher temperature throughout the cycle and a greater loss of heat through the cylinder walls than is the case when the charge is admitted to the cylinder at atmospheric temperature. The combined effect of these conditions is the imposition of an early limit to the compression ratio, on account of the increased liability to premature ignition due to the higher compression temperature and the lower ignition temperature of the oil vapor, as compared to those involved in the use of coal gas. Engines which do not use external vaporizers possess the inherent disadvantages of a higher compression pressure accompanied by a lower explosion pressure than those attained by engines of the vaporizer type. This indicates, that for a given size cylinder and a given quality of fuel, the mean effective pressure and consequently the power developed will be considerably lower in the former than in the latter.

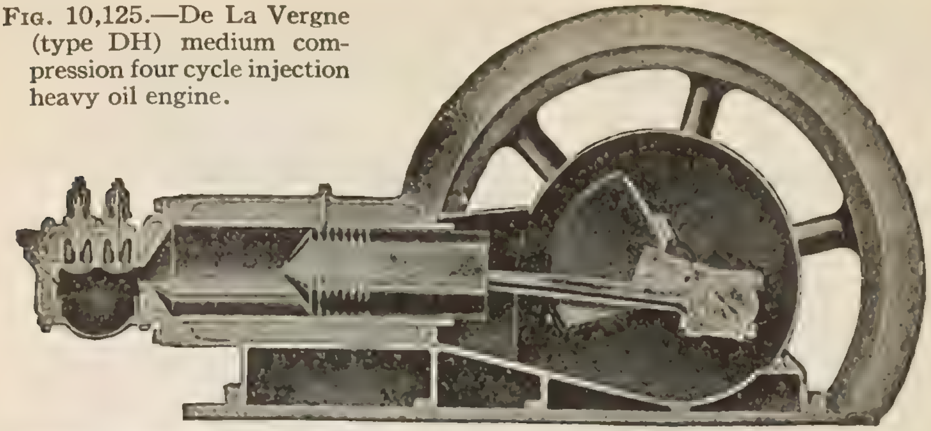


FIG. 10,125.—De La Vergne (type DH) medium compression four cycle injection heavy oil engine.

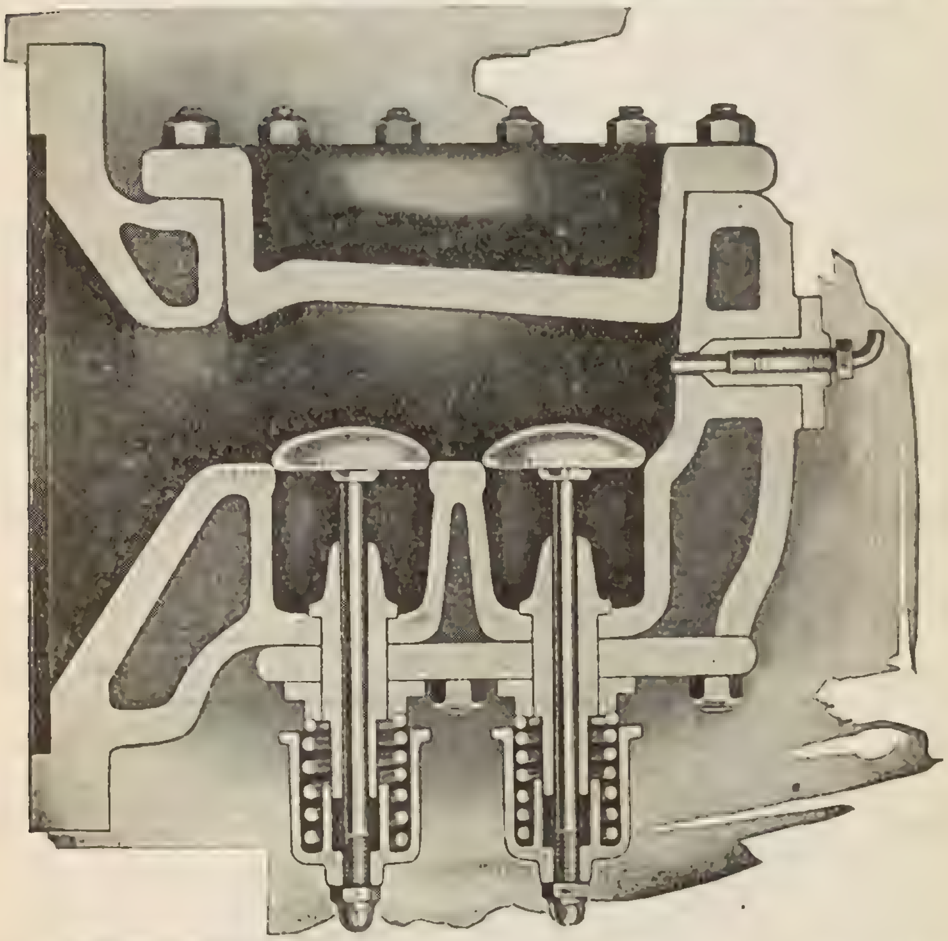
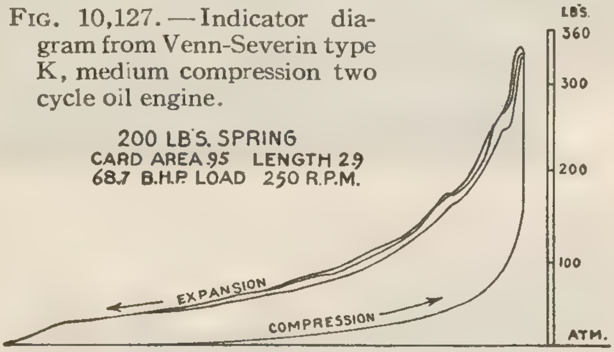


FIG. 10,126.—Cross section through vaporizer of De La Vergne (type DH) heavy oil engine. ***In operation*** the atomized fuel is injected against the hot (unjacketed) walls of the vaporizer where it is ignited by the combined heat of the valves and that due to the compression of the charge. In this arrangement pre-ignition and back firing are impossible as no fuel is introduced until the moment when ignition is desired.

pressure (more or less). Near the end of the stroke, the oil is injected into the vaporizer in the form of spray by the fuel pump. Coming into contact with the heated air, rich in oxygen, and striking the hot surface, vaporizes and ignites.

Power Stroke.—The resulting pressure of combustion drives the piston forward, transmitting energy to the fly wheel

FIG. 10,127.—Indicator diagram from Venn-Severin type K, medium compression two cycle oil engine.



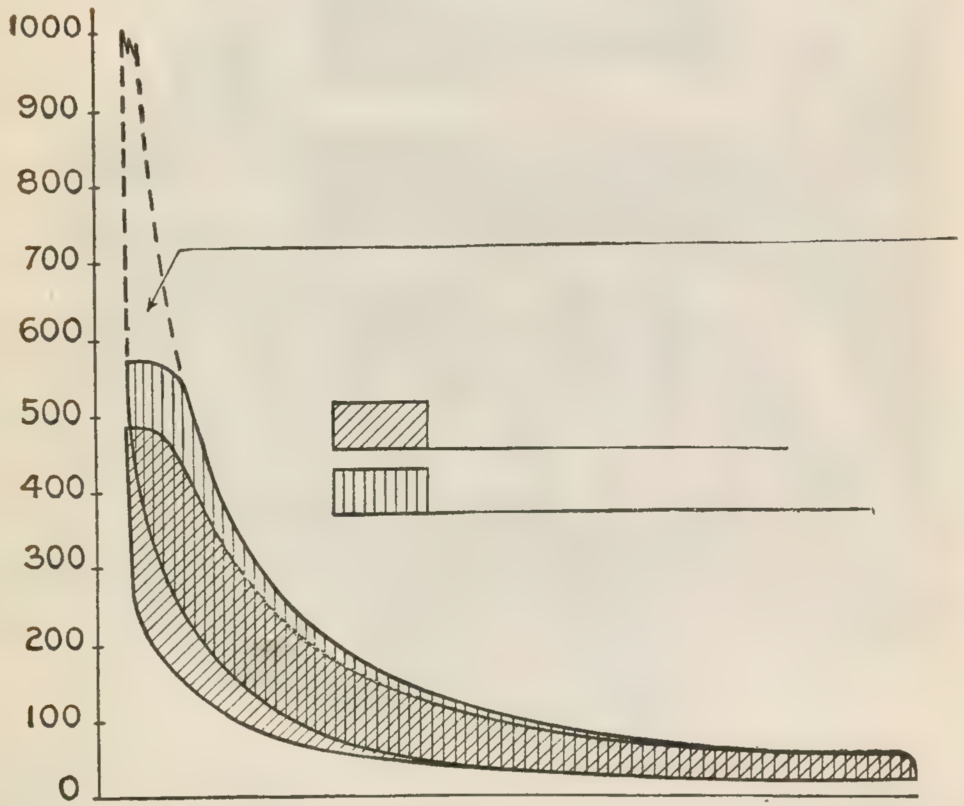
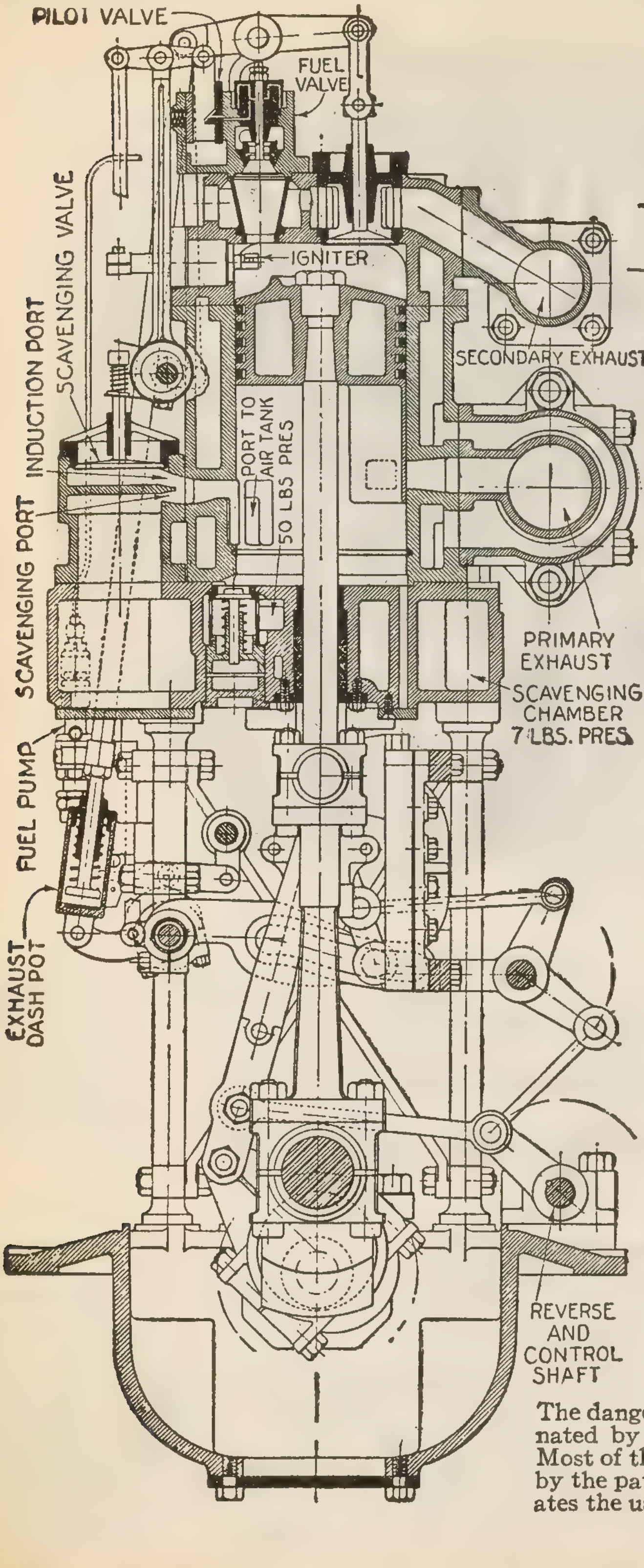
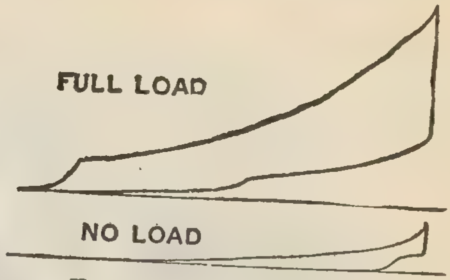


FIG. 10,128.—Comparison of indicator cards showing: 1, high compression cycle; 2, De La Vergne compression cycle, and 3, high compression cycle with faulty spray valve adjustment.





FIGS. 10,129 to 10,131.—Raabe variable compound compression, scavenging, reversible, marine oil engine. The easy working cycle and special valve gear permit a wide speed range, thus adapting it to lighters, tugs and other heavy working boats requiring quick control in manœuvring around docks, etc. the indicator cards, figs. 10,130 and 10,131, show full and no load operation. There is one impulse per revolution as in an ordinary two stroke cycle engine, although the actual cycle of this engine places it in a class by itself. The engine will run on the heaviest grades of fuel oil including tar oil with greater economy (as claimed) than the Diesel and permit a speed variation from rated speed to less than 5% of rated speed. For heavy duty the weight and size of these engines is less than 50% and for high speed work such as yachts torpedo boats, etc., less than 25% of that of Diesel engines of equal capacity. ***In operation,*** the oil is fed to the fuel valve by the fuel pump and fuel valve transforming the oil into an almost perfect gas during the charging period of the combustion chamber where it is mixed with the air previously admitted during scavenging. This explosive mixture is then ignited by electric ignition as in an ordinary gas engine and perfect combustion is obtained, due to the perfect transformation of of the oil from the liquid to the gaseous state. ***In starting,*** the fuel atomizer is electrically preheated; afterwards this heat is maintained by combustion. The danger of premature explosions is eliminated by the compound compression system. Most of the scavenging air enters the cylinder by the patented induction system which eliminates the use of large scavenging pumps.

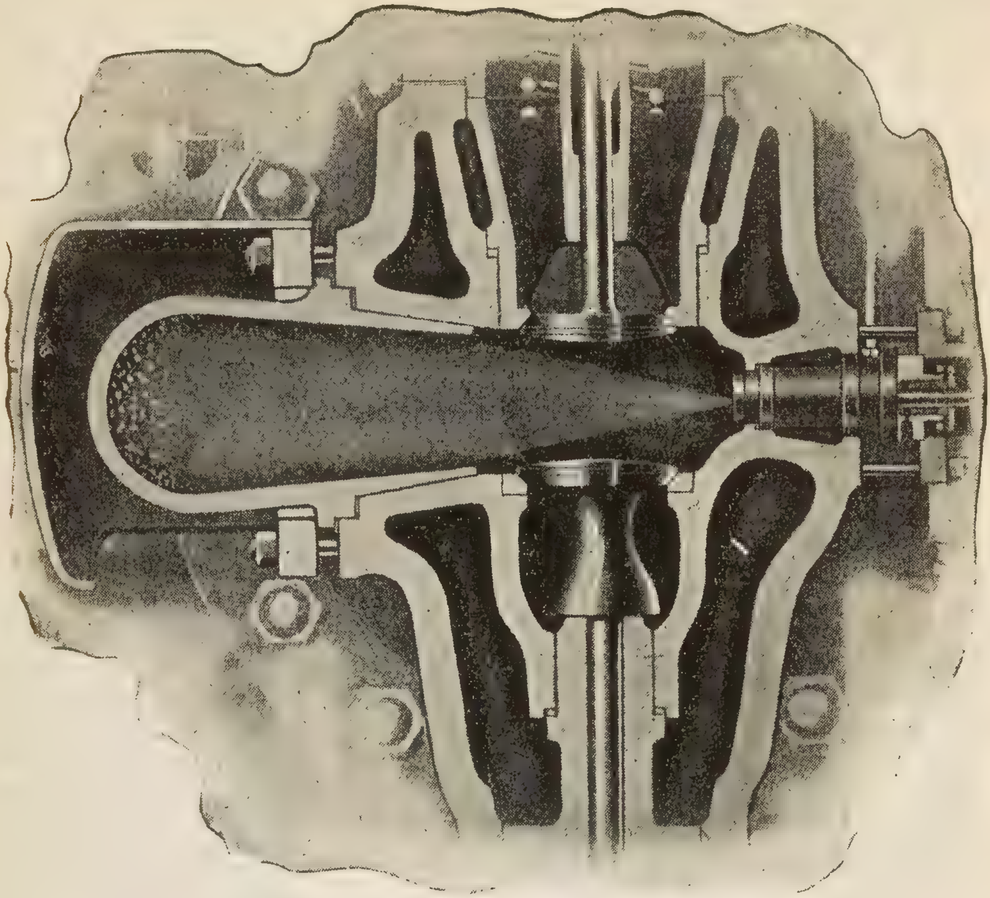


FIG. 10,132.—Cross section through cylinder of De La Vergne (type FH) ***semi-Diesel engine*** showing combustion chamber and valves. ***In starting,*** the combustion chamber is heated by a blast lamp for from 7 to 15 minutes and discontinued when the engine starts. The combustion of the fuel then maintains the chamber at the proper temperature. The engine is started automatically by admission of the air from the air tanks furnished for that purpose. ***To start,*** heat combustion chamber with the blast lamp, place crank in starting position and open the air cock. A cam on the lay shaft then successively opens and closes the starting valve at the proper times. When combustion has commenced and the engine begins to gather speed, the air cock should be closed. ***To stop,*** cut off the supply of fuel.

NOTE—***How to start a low compression two cycle oil engine.*** Previous to starting the engine, the igniter head is heated a few minutes by means of a gasoline blow torch, oil burner, gas burner or any other convenient method. When the igniter head is sufficiently heated and with the piston in proper position (ports closed) simply give the starting lever on the fuel pump a couple of sharp strokes to inject the initial charge of fuel into the combustion chamber. Then (in starting by hand) reverse fly wheel quickly, against compression, which compresses and ignites the charge, and the engine is under way, the fuel injection and ignition occurring thereafter automatically. ***In starting by air*** set the fly wheel so that the crank is just above back center, upon which a quick opening and closing of the lever handle throttle admits sufficient volume of air which under expansion quickly drives piston forward, setting fly wheel in motion. After starting the, torch or burner is extinguished

Exhaust Stroke.—The burnt gases are expelled from the cylinder.

Usually the air valve opens a few degrees before exhaust closes and a charge of fresh air is sucked into the vaporizer by the out rushing exhaust gases thus completing the scavenging.

Fig. 10,125 is an example of heavy oil engine of the medium compression type, and fig. 10,127 a typical indicator card of a medium compression engine.

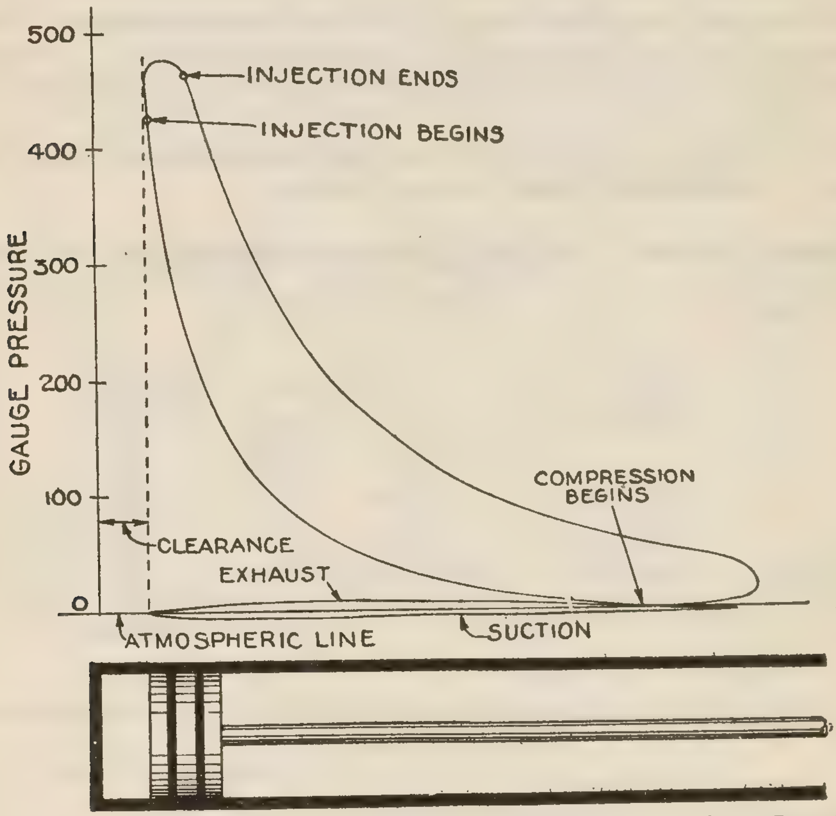


FIG. 10,133 and 10,334.—Typical indicator card of Diesel four cycle engine. *It will be noted* from the diagram that the pressure range and mean effective pressure is much greater than in other engines which accounts for the massive construction.

Semi-Diesel Oil Engines.—This classification is applied to engines of the medium compression heavy oil type in which the fuel is injected by the combined pump and compressed air method. Engines of this class like those of the preceding type

depend on the combined heat of compression and that of the vaporizer for ignition.

The operating cycle requires four strokes as follows:

Suction Stroke.—Admission of a full charge of air into the cylinder.

Compression Stroke.—Compression of the air charge into the combustion space to 250 lbs. (more or less). At or near the end of the compression stroke, the fuel oil is delivered to the spray valve by the fuel pump and blown into the cylinder by air furnished by a compressor at a pressure above that due to compression in the engine cylinder. The charge thus injected into the cylinder being ignited by the heat of compression.

Power Stroke.—The resulting pressure of combustion drives the piston forward, transmitting energy to the fly wheel.

Exhaust Stroke.—The burnt gases are expelled from the cylinder.

CHAPTER 156

Electric Motors

In order to locate motor faults, and make ordinary adjustments and repairs that might occasionally be required of the plumber, he should have some knowledge of electricity. The following introductory outline will be found helpful.

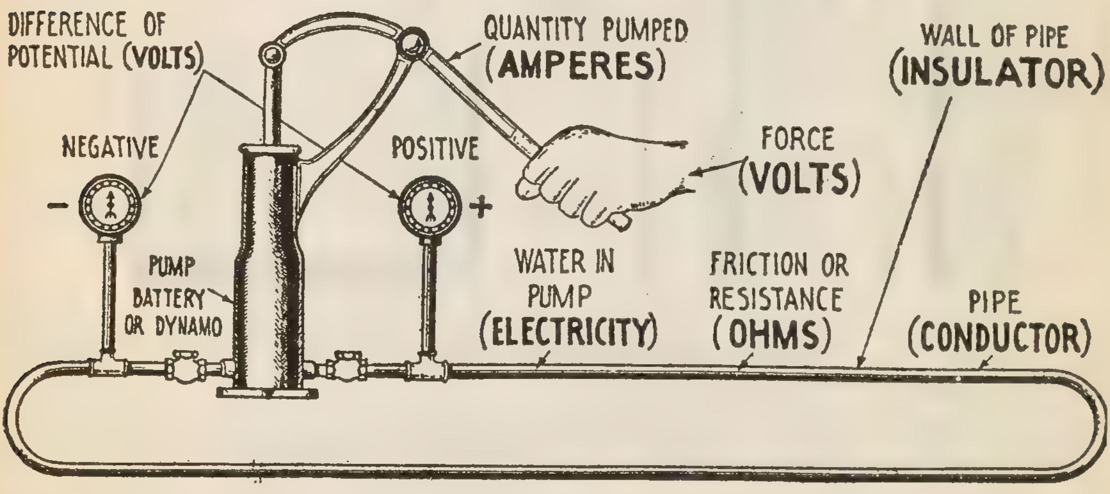


FIG. 10,135.—Hydraulic analogy of electric current.

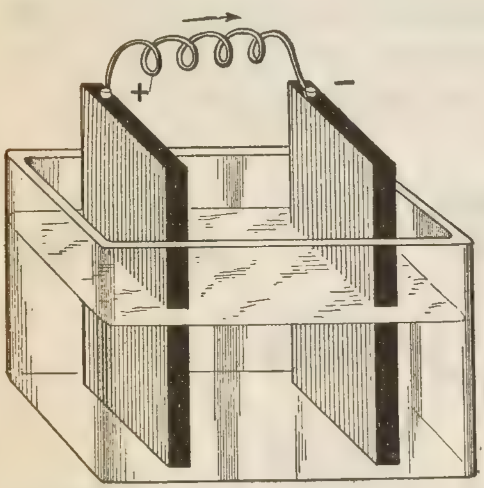
Electricity.—The name electricity is applied to an invisible agent known only by the effects which it produces, and the various ways in which it manifests itself.

Electrical *currents* are said to flow through *conductors*. These offer more or less *resistance* to the flow, depending on the material. Copper wire is generally used as it offers little resistance.

The current must have pressure to overcome the resistance of the conductor and flow along its surface. This pressure is called *voltage* caused by what is sometimes called *difference* of ***potential*** or better termed *difference of* ***pressure*** between the source and terminal.

An electric current has often been compared to water flowing through a pipe. The pressure under which the current flows is measured in *volts* and the quantity that passes in *amperes*. The resistance with which the current meets in flowing along the conductor is measured in *ohms*.

The flow of the current is proportional to the voltage and inversely proportional to the resistance. The latter depends upon the material, length and diameter of the conductor.



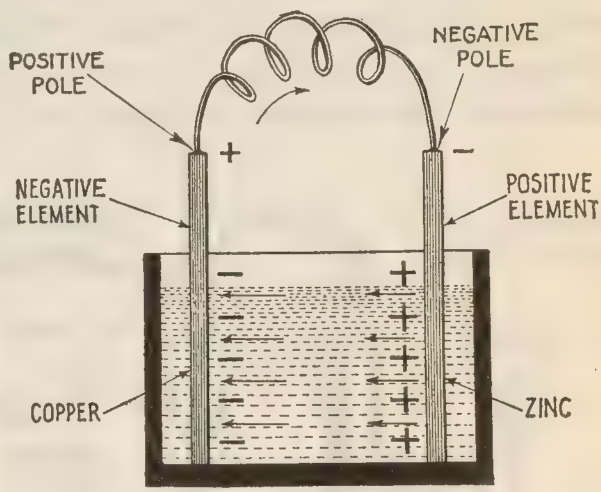


FIG. 10,136.—Simple primary cell. ***It consists of*** two dissimilar metal plates (such as copper and zinc which are called the *elements*) immersed in the electrolyte or exciting fluid contained in the glass jar.

FIG. 10,137.—Simple primary cell illustrating the terms poles and elements. ***Carefully note*** *that the* ***negative*** *element has* ***a positive*** *pole, and the* ***positive*** *element a* ***negative*** *pole.*

Since the current will always flow along the path of least resistance it must be so guarded that there will be no leakage. Hence to prevent leakage, wires are *insulated*, that is, covered by wrapping them with cotton, silk thread, or other insulating material. If the insulation be not effective, the current may leak, and so return to the source without doing its work. This is known as a *short circuit*.

The conductor which receives the current from the source is called the *lead*, and the one by which it flows back, the *return*. When wires are used for both lead and return, it is called a *metallic circuit*; when the ground is used for the return, it is called a *grounded circuit*.

An electric current is said to be:

1. *Direct*, when it is of unvarying direction;

2. *Alternating*, when it flows rapidly to and fro in opposite directions;

3. *Primary*, when it comes directly from the source;

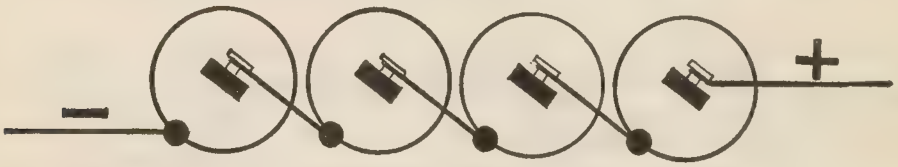


FIG. 10,138.—Series battery connection: The pressure between the (+) and (—) terminals of the *battery* is equal to *the product of the voltage of a single cell multiplied by the number of cells.*

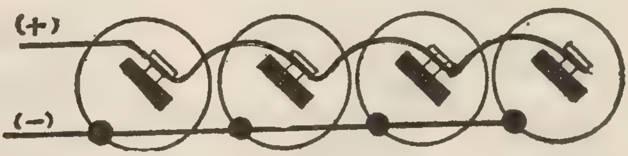


FIG. 10,139.—Multiple or parallel connection. The voltage *is the same as that of a single cell,* but the current is equal to the *amperage of a single cell multiplied by the number of cells.*

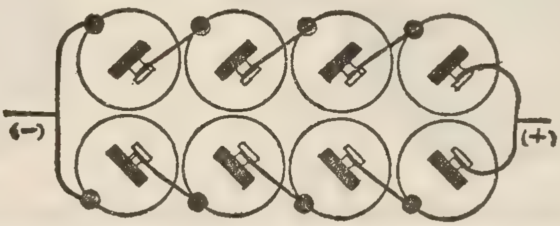


FIG. 10,140.—Series parallel connection. The pressure equals *the voltage o jone cell, multiplied by the number of cells in one battery,* and the amperage, *that of one cell multiplied by the number of batteries.* This form of connection is objectionable unless all the cells be of equal strength.

4. *Secondary*, when the voltage and amperage of a primary current have been changed by a transformer, or *induction coil.*

A current is spoken of as *low tension*, or *high tension*, according as the voltage is low or high. A high tension current is capable of forcing its way against considerable resistance, whereas, a low tension current must have its path made easy. A continuous metal path is an easy one, but an interruption in the metal is difficult to *bridge*, because air is a very poor conductor.

Air is such a poor conductor that it is usually, *though erroneously*, spoken of as a "non-conductor" it is properly called an *insulator*.

Magnetism.—The ancients applied the word "magnet," *magnus lapes*, to certain hard black stones which possess the property of attracting small pieces of iron, and as discovered

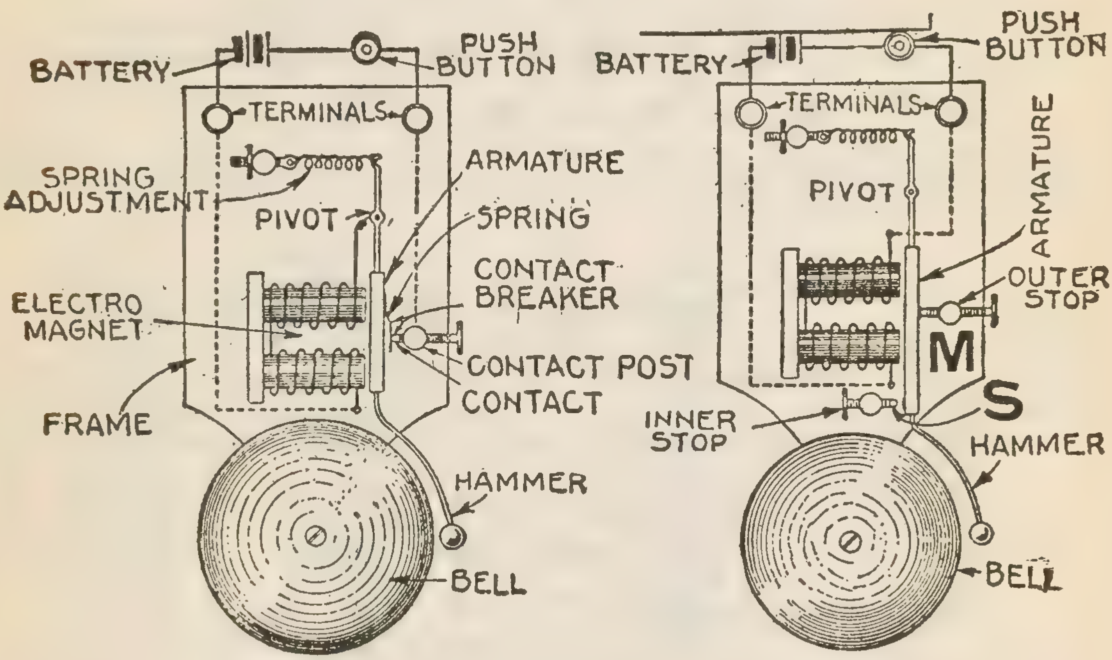


FIG. 10,141.—Elementary series vibrating bell. ***It consists of*** an electro-magnet, armature, contact breaker, pivoted hammer, bell, and frame. ***In operation,*** when the push button is pressed, the current energizes the magnet which attracts the armature causing the hammer to strike the bell, but before it reaches the end of the stroke, the contact breaker breaks the circuit and the hammer, influenced by the tension of the armature spring rapidly moves back to its initial position thus completing the cycle

FIG. 10,142.—Elementary single stroke bell. ***In operation,*** when the push button is pressed, the current energizes the magnet and attracts the armature causing the hammer to strike the bell. The armature remains in the attracted position so long as the current flows through the magnet. When connection with the battery is broken, the hammer spring pulls the armature back against **M**. A stop **S**, averts the motion of the armature, momentum springing the lever and causing the hammer to strike the bell.

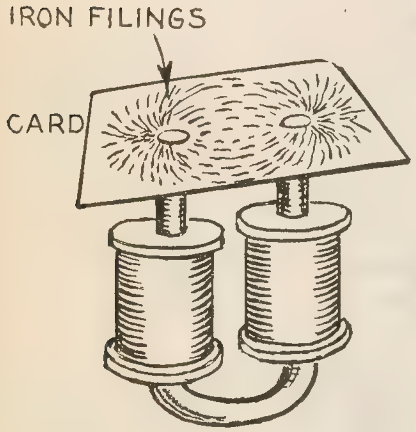
later, to have the still more remarkable property of pointing north and south when hung up by a string; at this time the magnet received the name *lodestone*.

Magnets have two opposite kinds of magnetism or magnetic poles which attract or repel each other in much the same way as would two opposite kinds of electrification.

One of these kinds of magnetism has a tendency to move toward the north and the other, toward the south. The two regions, in which the magnetic property is strongest, are called the *poles*. In a long shaped magnet it resides in the ends, while all around the magnet half way between the poles there is no attraction at all.

The poles of a magnet are usually spoken of as *north pole* and *south pole*.

When a current of electricity passes through a wire, a certain change is produced in the surrounding space producing what is known as a magnetic



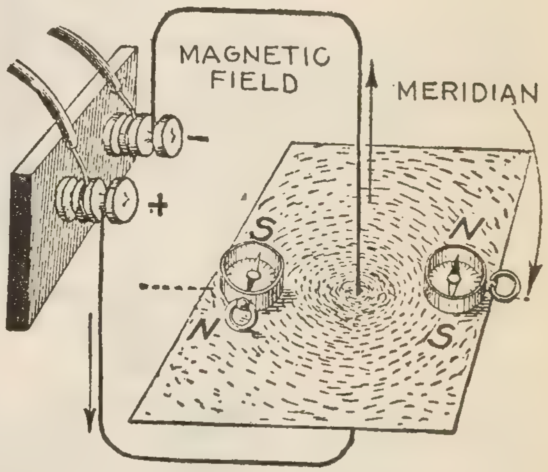


Fig. 10,143.—Ordinary horse shoe magnet with iron filings showing magnetic field.

Fig. 10,144.—Electromagnetic field surrounding a conductor with current flowing.

field. If the wire be insulated with a covering and coiled around a soft iron rod, it becomes an electro-magnet having a north and south pole, *so long as the current continues to flow*. The magnetic strength increases with the number of turns of the coil, for each turn adds its magnetic field to that of the other turns.

Induction.—If a second coil of wire be wound around the coil of an electro-magnet, but not touching it, an *induced current* is produced in this second coil by what is known as *induction*, each time the current in the inside coil begins or ceases flowing.

The inside coil is called the *primary winding* and the outside coil, the *secondary winding*. Similarly, the current passing through the inside coil is called the *primary current*, and that in the outside coil, the *secondary* or *induced current*.

It has been found that by varying the ratio of the number of turns in the two coils the tension or voltage of the two currents is changed proportionately. That is, if the primary winding be composed of ten turns and the secondary of one hundred, the voltage of the secondary current is increased ten times that of the primary. This principle is employed in the construction of induction coils and transformers.

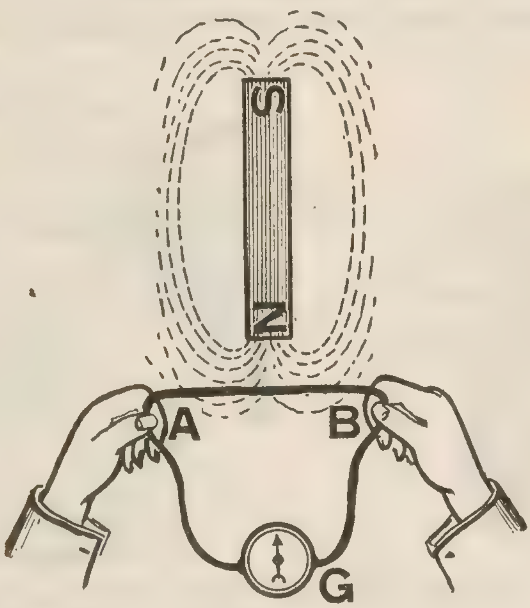


FIG. 10,145.—***Faraday's discovery:*** If a loop of wire be connected to a galvanometer and a section of the wire AB, be moved through a magnetic field as shown, the galvanometer will be deflected indicating that an electric current is generated when *a conductor is moved in a magnetic field so as to* ***cut*** *lines of force*. A thorough understanding of the term ***cut*** *lines of force* is highly important.

Electrical Units.—The following units should be thoroughly understood:

Volt.—The force or pressure which will produce a current of one ampere in a circuit having a resistance of one ohm.

Ampere.—The current produced by a force or pressure of one volt in a circuit having a resistance of one ohm.

Ohm.—The resistance of an electric current by a column of mercury

one square millimeter in section and 106 centimeters long, at a temperature of 0° C.

Watt.—The product of one ampere multiplied by one volt.

Kilowatt.—1,000 watts.

Electrical Horse Power.—The unit of electrical work being the mechanical horse power expressed in watts. It is equal to 746 watts.

Ohm's Law.—In a given circuit, the amount of current in amperes is equal to the pressure in volts divided by the resistance in ohms.

Alternating Current.—By definition, alternating current is a *current which reverses its direction in a periodic manner, rising from zero to maximum strength, returning to zero, and then going*

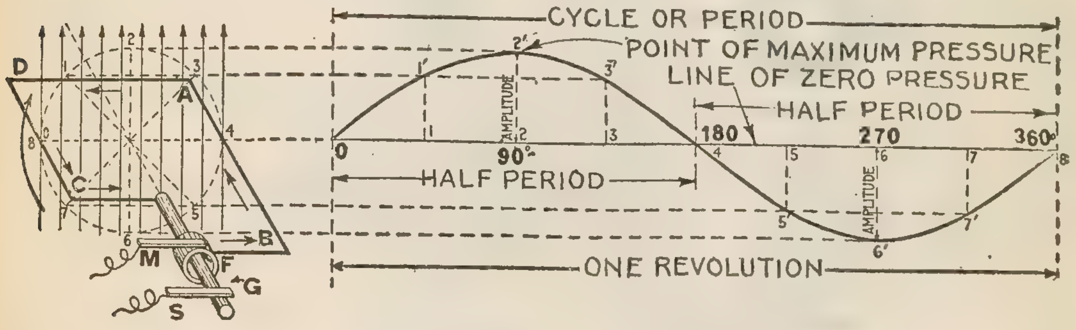


FIG. 10,146.—Alternating current represented by the ***sine curve.*** As the elementrary alternator rotates, the induced elect ricpressure will vary in such a manner that *its intensity at any point of the rotation is proportional to the sine of the angle corresponding to that point.* Hence, on the horizontal line which passes through the center of the dotted circle, take any length as 08, and divide into any number of equal parts representing fractions of a revolution, as 0°, 90°, 180°, etc. Erect perpendiculars at these points and from the corresponding points on the dotted circle project lines (parallel to 08) to the perpendiculars; these intersections give points, on the sine curve. The curve lies above the horizontal axis during the first half of the revolution and below it during the second half, which indicates that the current flows in one direction for a half revolution, and in the opposite direction during the remainder of the revolution.

through similar variations in strength in the opposite direction; these changes comprise the *cycle* which is repeated with great rapidity.

The advantage of alternating current (*a.c.*) over direct current (*d.c.*) lies in the reduced cost of transmission by use of high voltages and transformers, greater simplicity of alternators and *a.c.* motors, facility of transforming from one voltage to another (either higher or lower) for different purposes.

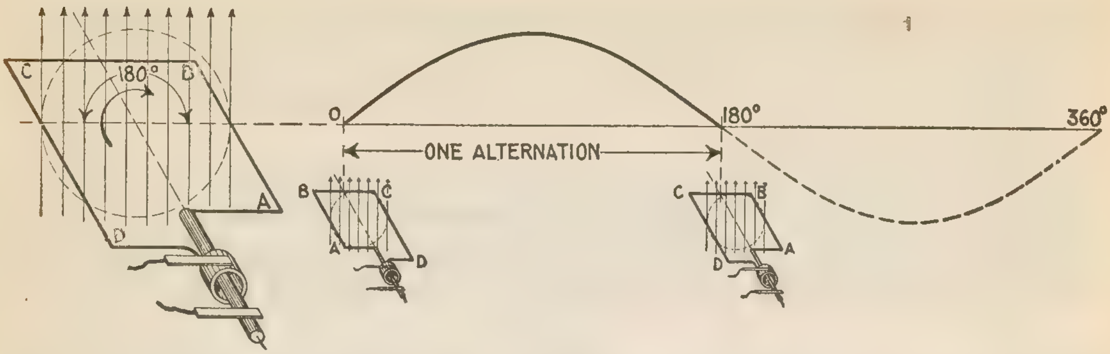


FIG. 10,147.—Diagram showing one *alternation* of the current in which the latter varies from zero to maximum and back to zero while the generating loop ABCD, makes one half revolution.

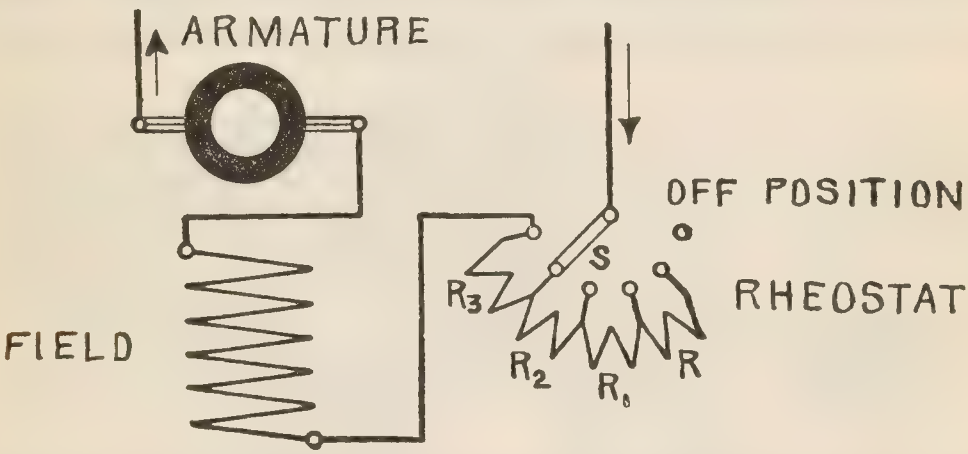


FIG. 10,148.—Series motor connections. ***To start the motor,*** the circuit is completed through a variable resistance or rheostat by moving the switch S, so that the resistances R, R_1,R_2,R_3. are gradually cut out of the circuit. ***To stop,*** the switch S, is moved back to its "off" position.

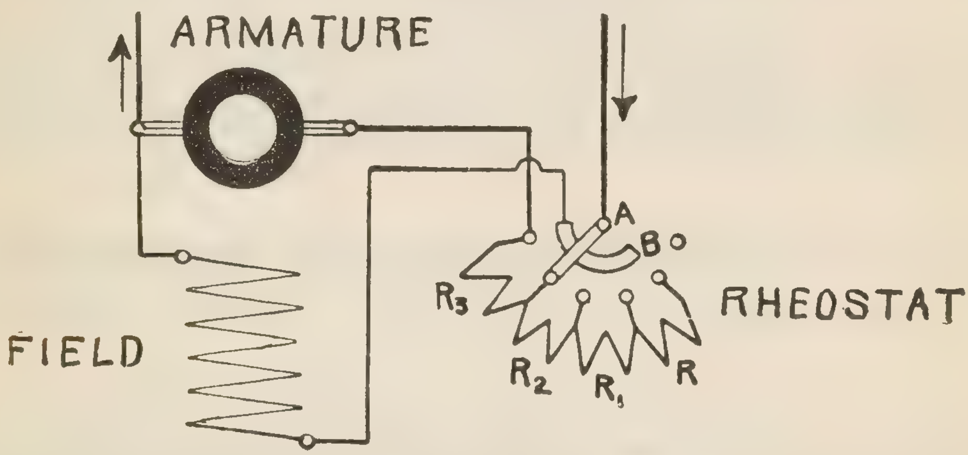
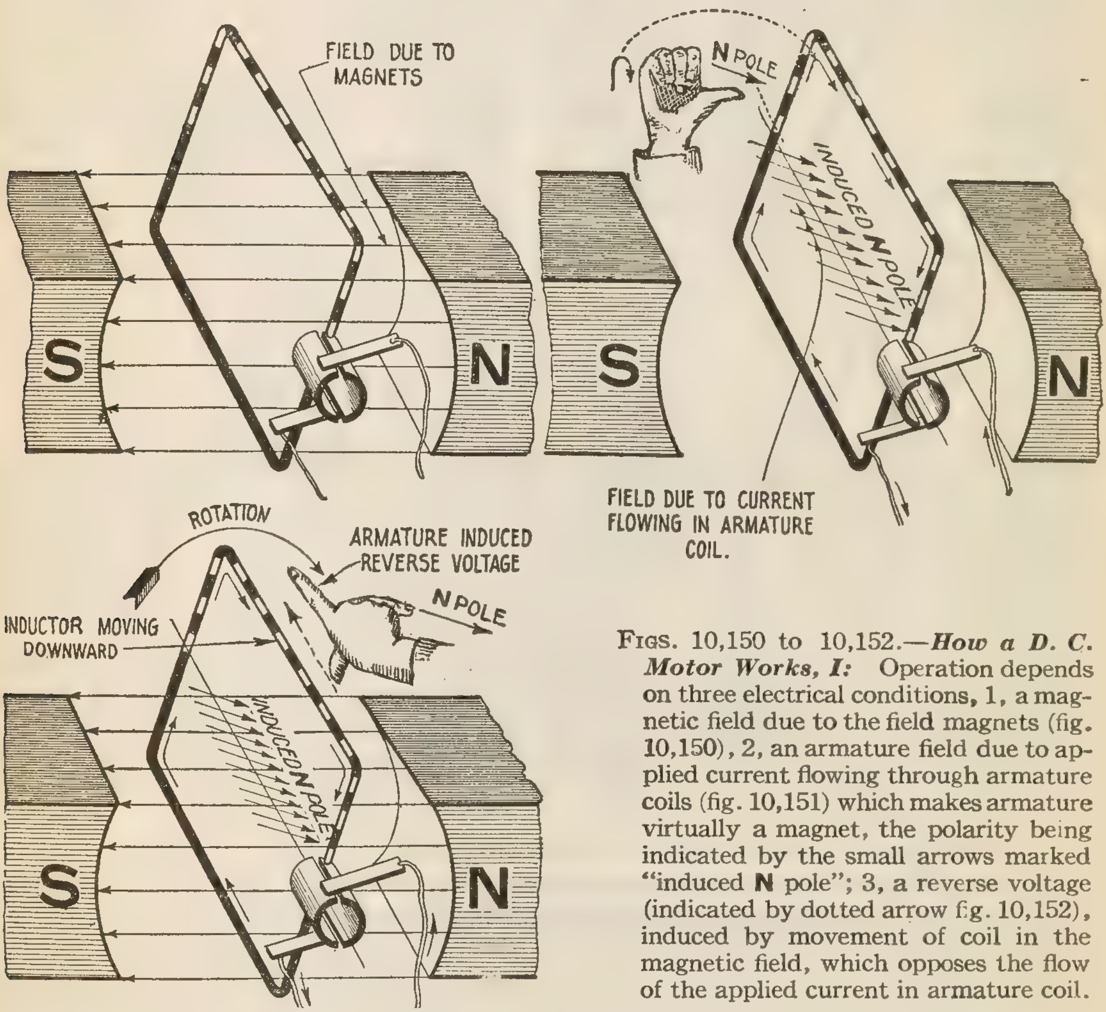


FIG. 10,149.—Shunt motor connections. ***In starting,*** *unless the field magnets be put in the circuit* ***first,*** the armature, at rest, because of its low resistance would probably burn out.

The disadvantages of alternating current are: 1, the high pressure at which it is used renders it dangerous, requiring more efficient insulation; 2, alternating current cannot be used for such purposes as electroplating, charging storage batteries, etc.

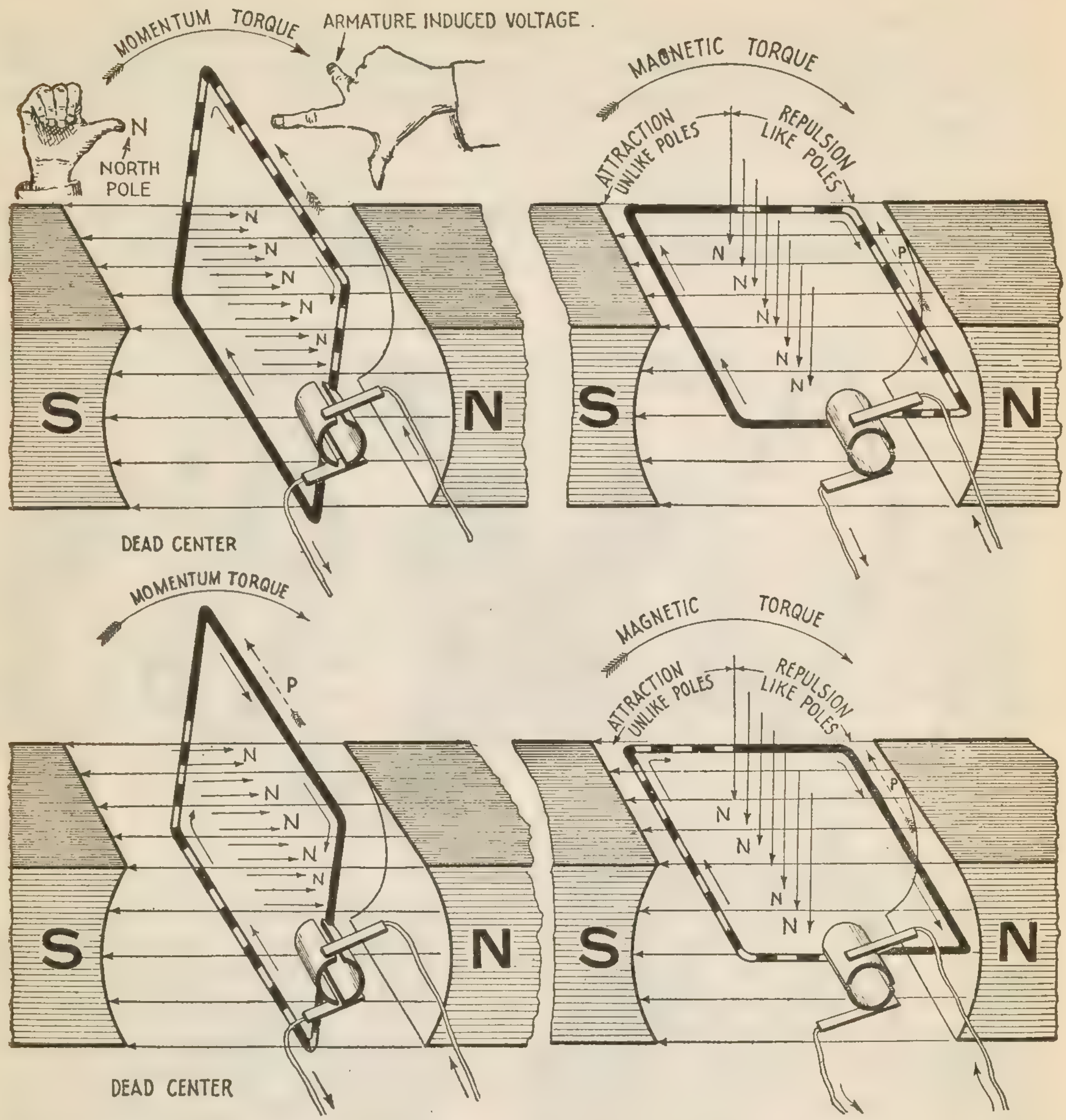
D.C. Motors.—A motor is *a machine for converting electrical energy into mechanical energy;* it is constructed in the same



FIGS. 10,150 to 10,152.—***How a D. C. Motor Works, I:*** Operation depends on three electrical conditions, 1, a magnetic field due to the field magnets (fig. 10,150), 2, an armature field due to applied current flowing through armature coils (fig. 10,151) which makes armature virtually a magnet, the polarity being indicated by the small arrows marked "induced **N** pole"; 3, a reverse voltage (indicated by dotted arrow fig. 10,152), induced by movement of coil in the magnetic field, which opposes the flow of the applied current in armature coil.

FIG. 10,149.—*Text continued.*

To start, the switch is closed, and the rheostat lever pushed over so as to make contact with A and B, thus *first* exciting the magnets. On further movement of the lever, the rheostat resistances R,R_1,R_2,R_3, etc., are gradually cut out as the speed increases until finally all the resistance coils are cut out. ***To stop,*** the lever is brought back to its original position.



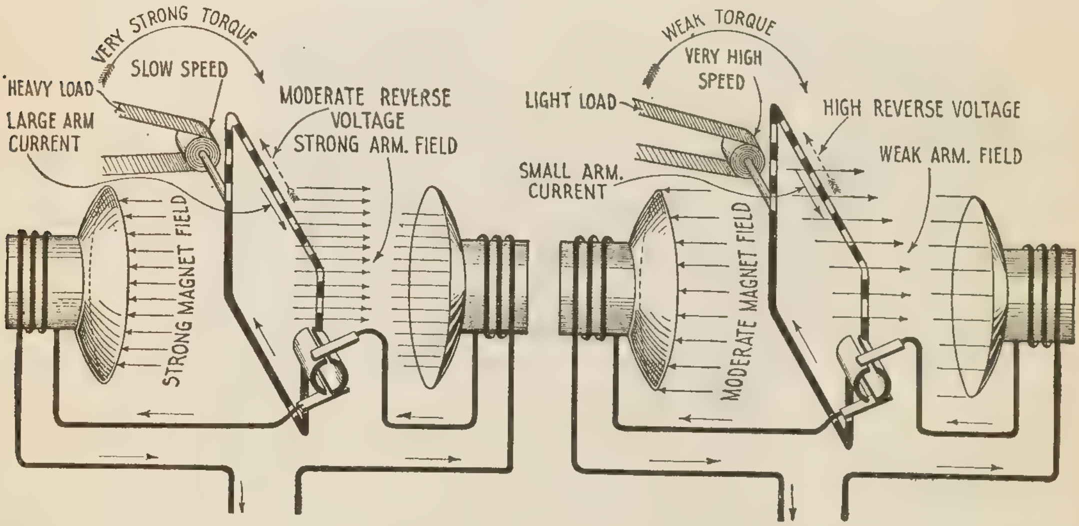
FIGS. 10,153 to 10,156.—***How D.C. Motor Works, II:*** Cycle of operation: Fig. 10,153, beginning of revolution, armature and magnet poles in opposite directions and hence *they* ("like" poles) ***oppose each other***. This is the dead center position as there is no magnetic tendency to rotate armature, since magnetic lines of magnets and armature are parallel, but *momentum* of the armature (assumed to be rotating) carries it past this dead center (just as a steam engine passes its dead center), when a clockwise torque is produced by the opposition of like poles. Fig. 10,154, ¼ revolution position, armature poles at right angles or midway between magnet poles; here the torque is due to *the* ***equal*** *turning forces of* ***repulsion*** *of like poles and* ***attraction*** *of* ***unlike*** *poles*. Fig. 10,155, ½ revolution position; at this instant *the armature polarity* ***is reversed*** by the reversal of current flowing in the armature coil due to brushes passing to opposite segment of commutator; the magnetic lines being parallel, give a second dead center *with* ***like*** *poles* ***repelling*** *each other* similar as in fig. 10,156, ***momentum*** *carrying the*

manner as a dynamo. As with dynamos, there are three general types of motors:

1. Series; 2. Shunt; 3. Compound.

Their characteristics are given below.

Series Motor.—It is inherently a variable speed motor starting with very powerful torque. On very light load the speed becomes dangerously



FIGS. 10,157 and 10,158.—***How a D. C. Motor Works, III: Series motor with variable load.*** Since the same current passes through both the armature and field coils *the strength of the magnet field varies with that of the armature field.* Now if a heavy load cause the motor to slow down as in fig. 10,157, the reverse voltage will be reduced and a large current will flow through both armature and magnets producing a very strong torque to carry the load. Again, if the load be reduced, as in fig. 10,158, the motor will speed up and increase the reverse voltage which by cutting down the current will weaken both the armature and magnet fields until equilibrium with the load is established.

high, hence it should be used only where the load is never entirely removed or where close attention is maintained. *Should **never** be used with a belt,* but always by coupling chain or gear. Used chiefly for hoists, cranes, street railways and fans.

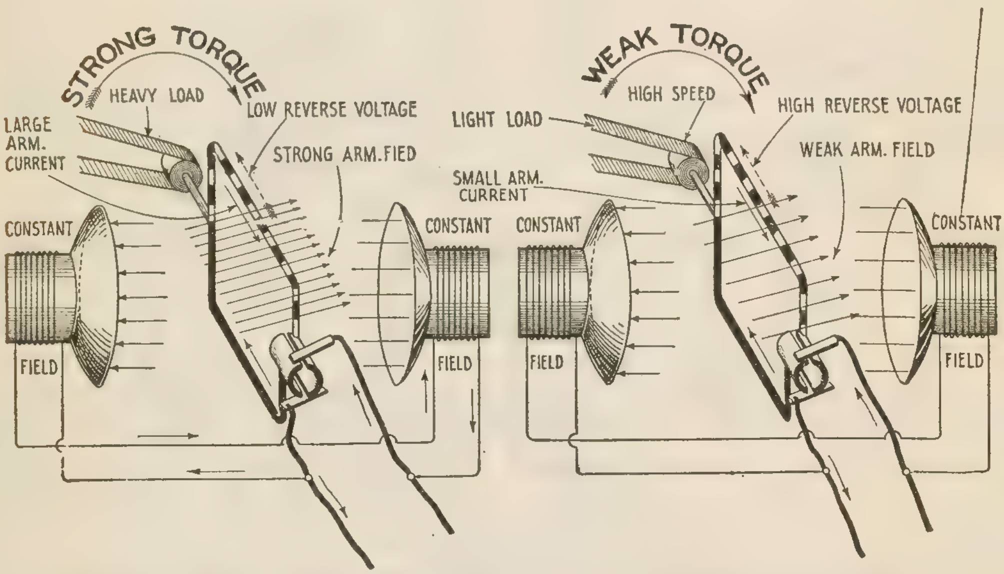
FIGS. 10,153 to 10,156.—*Text continued.*

armature past the dead center. Fig. 10,156, ¾ revolution position, armature poles *again* at right angles or midway between magnet poles; here (as in fig. 10,154) the torque is due to the equal *turning forces of **repulsion of like poles*** and ***attraction of unlike poles.*** Now at all times the rotation of the armature induces an electric pressure in the coil in a direction opposite to the current applied to the armature as indicated by the dotted arrow, called the ***reverse voltage***; which tends to reduce the current applied to armature.

Shunt Motor.—The speed is practically constant. It will not start heavy loads, and is best adapted to constant loads such as pumps, fans, etc.

Compound Motor.—Since this motor is a combination of the shunt and series types, it partakes of the properties of both. The series winding gives it strong torque at starting (though not as strong as in the series motor), while the presence of the shunt winding prevents excessive speed. The speed is practically constant under all loads within the capacity of the machine.

A compound motor should be used in preference to a shunt motor where



FIGS. 10,158 and 10,160.—***How a D. C. Motor Works, IV:*** *Shunt motor with variable load. The strength of the magnet field remain constant while that of the armature field varies.* Now if a heavy load cause the motor to slow down as in fig. 10,158, the reverse voltage will be reduced allowing more current to flow through the armature which increases the torque till equilibirum is established between torque and load. Again, if the load be reduced, the motor will speed up, and since the field strength remains constant (instead of being reduced as in the series motor) this acceleration is quickly checked by the rapid rise of reverse voltage, there being very little difference in speed for either heavy or light load.

frequent starting and reversing are necessary. For severe mill service, the winding is heavily compounded (called *over-compounded*), having only enough shunt winding to limit the light load speed. At heavy loads such motors act virtually as series motors.

A series motor has usually only two terminals coming out from the case, whereas a shunt machine has three or four; three, by bringing together one armature and one field terminal inside of machine, if the direction of rotation be fixed.

A.C. Motors.—There are numerous kinds of alternating current motors which may be classed as:

1. SYNCHRONOUS MOTORS
2. ASYNCHRONOUS MOTORS

a. **Induction motors**

b. **Commutator motors** { *series; compensated; shunt;* ***repulsion.***

1. Synchronous Motors

The term "synchronous" means *in unison*, that is, *in step*. A so called synchronous motor, then, as generally defined, *is one which rotates in unison or in step with the phase of the alternating current which operates it.*

Strictly speaking, however, it should be noted that this condition of operation is only approximately realized as will be later shown.

In construction, synchronous motors are almost identical with the corresponding alternator and consists essentially of, 1, *an armature*, and 2, *a field*, either of which may revolve.

The field is separately excited with direct current. In operation, when the field is thus excited and alternating current is applied to the armature of a single phase motor, it will produce alternately N, and S, poles, the reaction between these *induced* poles and the *field* poles tending to rotate the armature first in one direction, then in the other.

Because of the very rapid reversals in direction of the torque thus set up, there is not sufficient time ***to overcome the inertia of the armature*** *before the current reverses and produces a torque in the opposite direction, hence, the armature remains stationary or, strictly speaking,* ***it vibrates.***

Now if the motor armature be first brought up to a speed corresponding in frequency to that of the alternator before connecting the motor

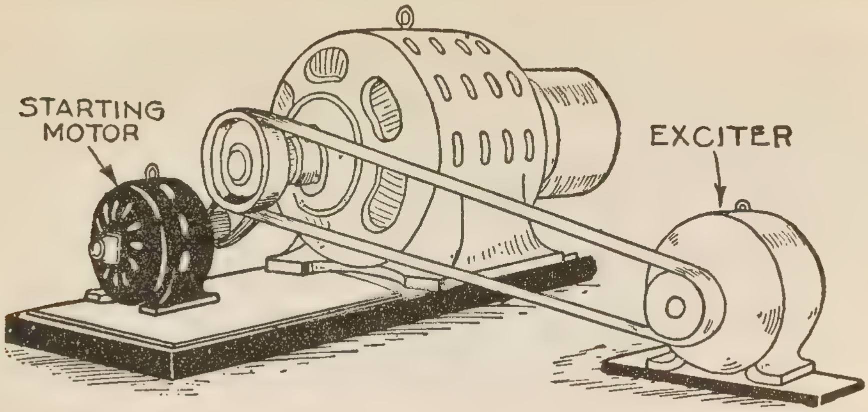


FIG. 10,161.—*Auxiliary starting* type synchronous motor, showing exciter and starting induction motor.

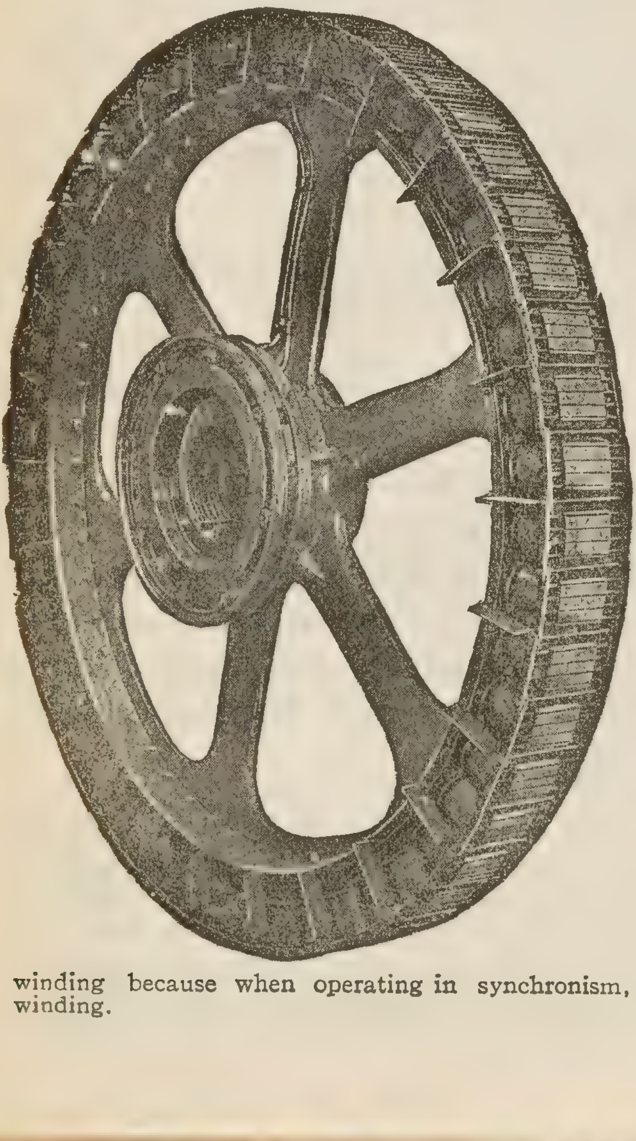


FIG. 10,162.—Rotor field of General Electric 360 horse power *self-starting* type synchronous motor, showing the amortisseur or squirrel cage starting winding in the pole faces. The synchronous motor can use a high resistance squirrel cage winding because when operating in synchronism, there is practically no loss in the winding.

in the circuit, the armature will continue revolving at the same frequency as the alternator.

The armature continues revolving, because at ***synchronous speed,*** *the field flux and armature current are always in the same relative position,* producing a torque which always pulls the armature around in the same direction.

A polyphase synchronous motor is self starting, because, before the

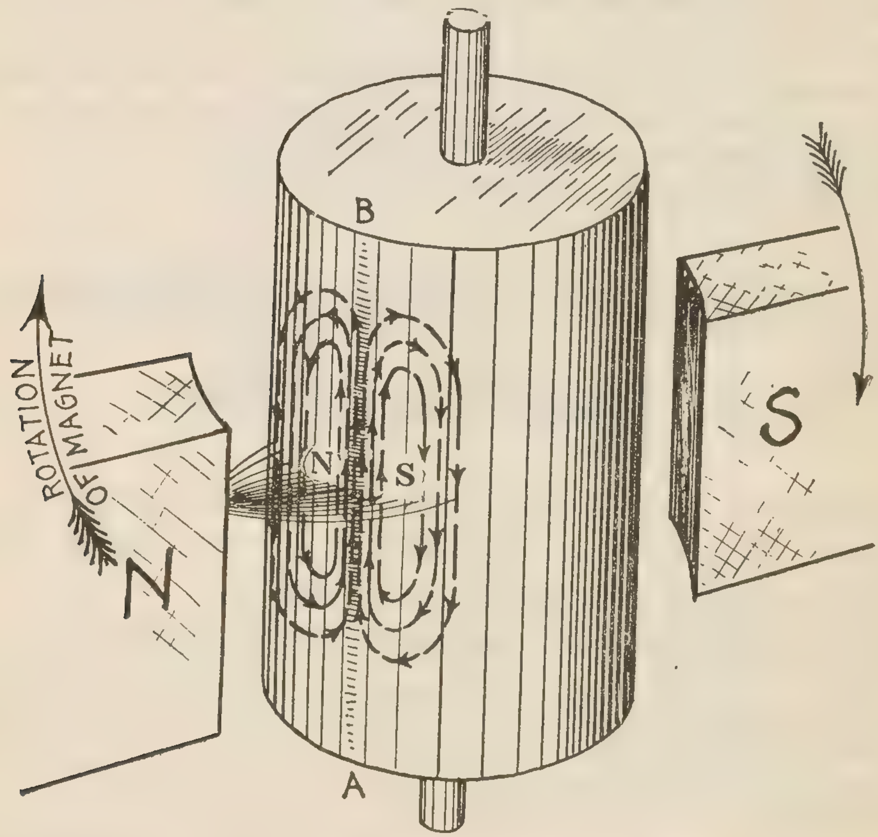


FIG. 10,163.—Elementary induction motor consisting of a copper cylinder and rotating magnet *illustrating the principle of operation of an induction motor* as explained in the accompanying text. ***In operation,*** the speed of the copper cylinder armature depends upon the load; it must always turn *slower* than the magnet, in order that its elements may cut magnetic lines and induce poles to produce the necessary torque to balance the load. The difference in speed of the magnet and cylinder is called the *slip*. Evidently the greater the load, the greater is the slip required to induce poles of sufficient strength to maintain equilibrium. The figure is drawn somewhat distorted, so that both eddies are visible. Obviously in practice, a better result is obtained if the downward returning currents of the eddies are led into some path where they will return across a field of opposite polarity from that across which they ascended, as in such case, the turning effect will be doubled. Such modification was made by cutting a number of parallel slits in the copper cylinder, leaving at each end an uninterrupted *ring* of metal, hence the name "squirrel cage."

current has died out in the coils of one phase, it is increasing in those of the other phase or phases, so that there is always some turning effort exerted on the armature.

The speed of a synchronous motor is that at which it would have to run, if driven as an alternator, to deliver the number of cycles which is given by the supply alternator.

Any synchronous motor if supplied with motive power can be converted without any change to an alternator or any alternator can be run as a synchronous motor if supplied with an alternating current of the same voltage and phase values.

Synchronous motors are used principally for power factor corrections, such as in a plant, where a large inductive load is used such as arc lamps, transformers, and motors, which reduces the power factors so much, that it causes trouble at the power house.

2. Asynchronous Motors

a. Induction Motors

An induction motor consists essentially of an armature and a field magnet, there being, in the simplest and most usual types, no electrical connection between these two parts.

There are two general types of induction motor:

1. Single phase;
2. Polyphase.

The operation of an induction motor depends on the production of a magnetic field by passing an alternating current through field magnets.

The character of this field is either ***oscillating*** *or* ***rotating,*** *according, as single or* ***polyphase*** *current is respectively used.*

The principle of operation of an induction motor is shown in fig. 10,163.

Starting of Induction Motors.—Because of the very low resistance of the armature, the machine, unless of very small size, would probably be destroyed by the heat generated before it could come up to speed. Accordingly some form of starting device is necessary. There are several methods of starting, as with:

1. Resistances in the field;
2. Auto-transformer or compensator;

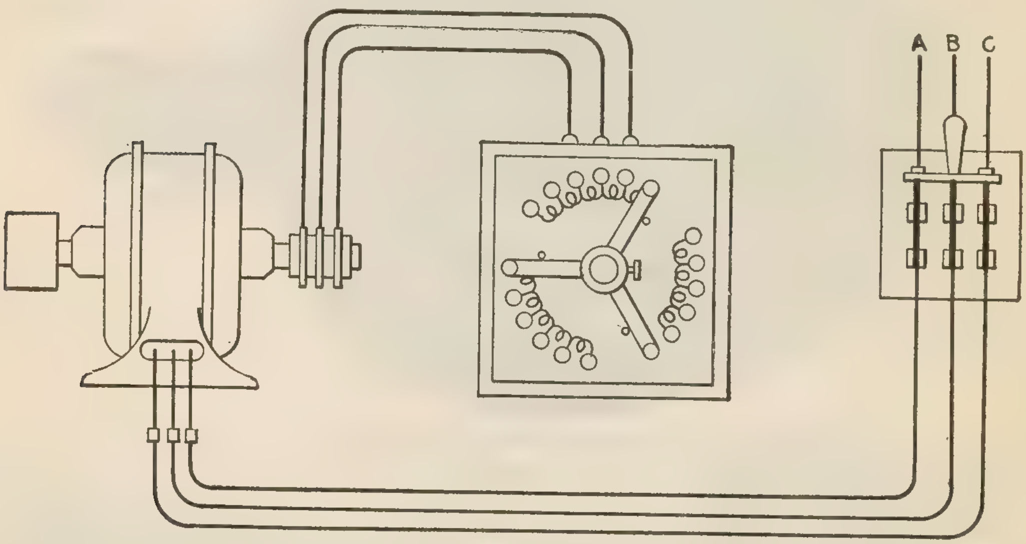


FIG. 10,164.—External resistance or slip ring induction motor connections. The squirrel cage armature winding is not short circuited by copper end rings, but connected in Y grouping and the three free ends connected to three slip rings, leads going from the brushes to three external resistances, arranged as triplex rheostat having three arms rigidly connected as shown, so that the three resistances may be varied simultaneously and in equal amounts.

3. Resistance in armature.

In the first method variable resistances are inserted in the circuits leading to the field magnets and mechanically arranged so that the resistances are varied simultaneously for each phase in equal amounts. These starting resistances are enclosed in a box similar to a direct current motor rheostat.

An objection to this method is that it is less efficient than the use of variable inductances.

In the second method, variable inductances or auto-transformers are inserted in the field magnet circuits.

In the third method, variable resistances are inserted in the armature circuit, and according to the location of these resistances, the machine is classed as an internal resistance motor, or an external resistance (slip ring) motor.

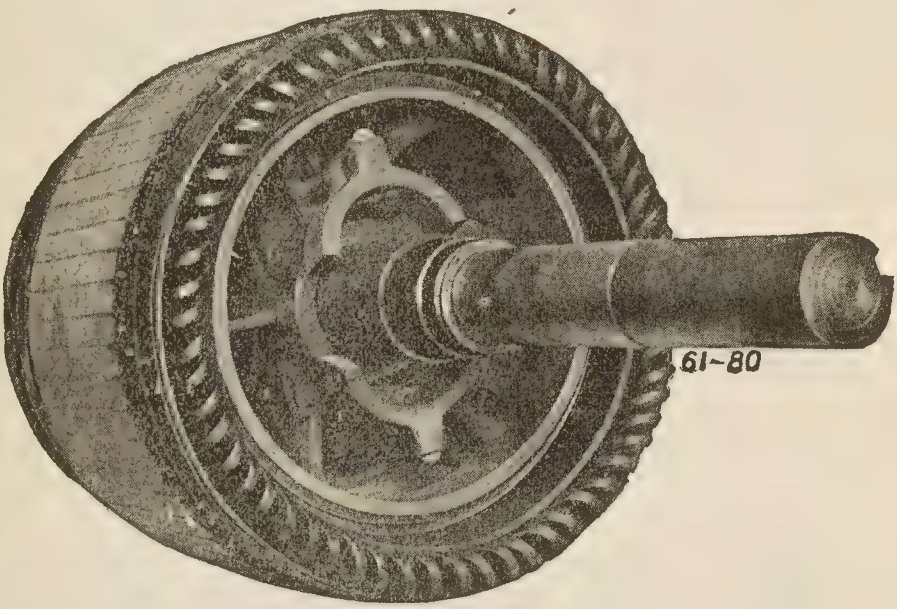


FIG. 10,165.—View of armature interior of Wagner poplyphase induction motor with wound armature, showing the centrifugal device which at the proper speed short circuits all the coils, transforming the motor to the squirrel cage type. The winding is connected with a vertical "commutator" so called. Inside the armature are two governor weights, which are thrown outward by the centrifugal force when the machine reaches the proper speed thus pushing a solid copper ring (which encircles the shaft) into contact with the inner ends of the "commutator" bars, in this way completely short circuiting the armature winding.

Internal Resistance Induction Motors.—The armature of this type of induction motor differs from the squirrel cage variety in that the winding is not short circuited through copper rings, but, in starting, is short circuited through a resistance mounted directly on the shaft in the interior of the armature.

When the motor is thrown in circuit, a very low starting current is drawn from the line due to the added resistance in the armature. As the motor comes up to speed, this resistance is gradually cut out, and at full speed the motor operates as a squirrel cage motor, with short circuited winding.

The starting resistance is gradually cut out by operating a lever which engages a collar free to slide horizontally on the shaft. The collar moves over the internal resistance grids (located within the armature spider), thus gradually reducing their value until they are cut out.

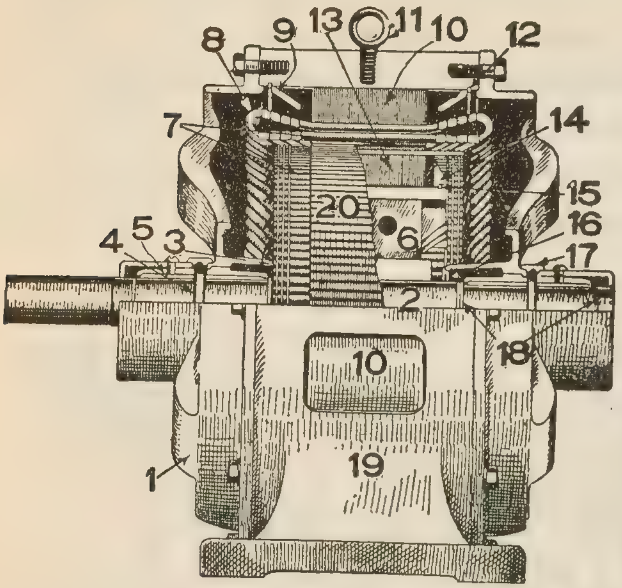
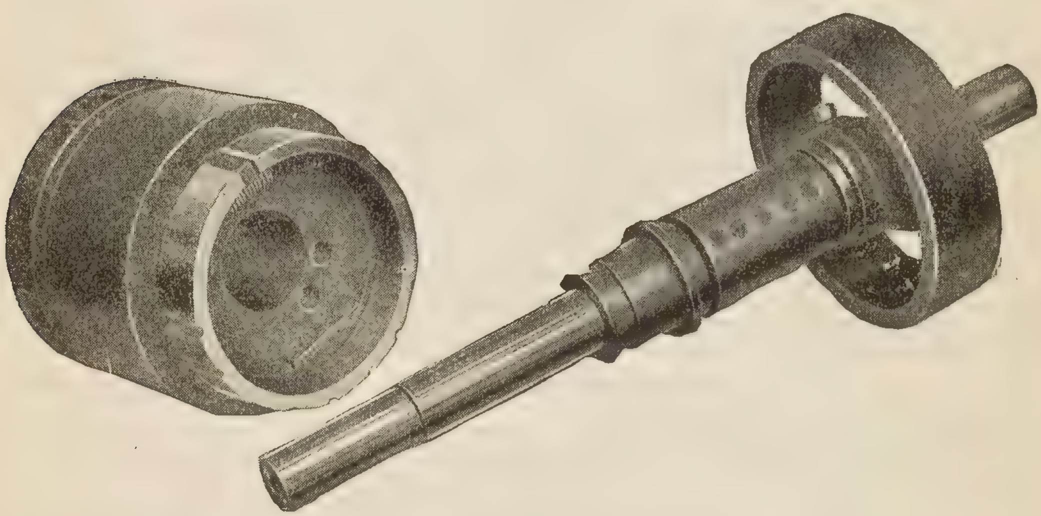


FIG. 10,166.—Sectional view of reliance polyphase induction motor.

This arrangement is suitable for small motors, but is objectionable on large motors because of the considerable heat produced.

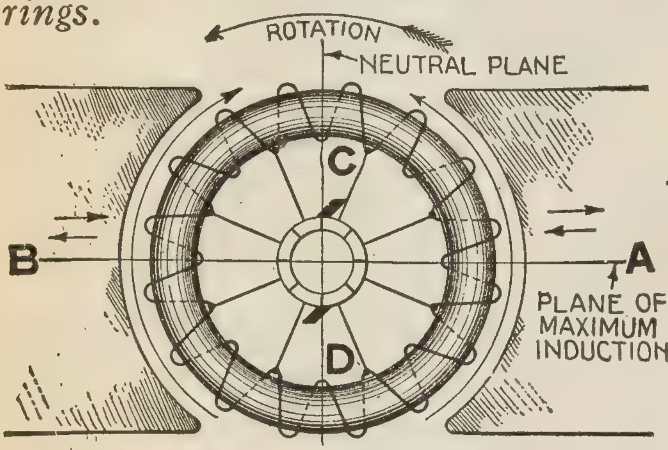
The initial rush of current when a squirrel cage motor is thrown on the line is more or less objectionable and there are central stations which allow only resistance type of induction motor to be used on their lines.

As with the internal resistance motor, the armature winding of a slip ring motor is not short circuited through copper rings in starting, but through a resistance, which in this case is located externally.



FIGS. 10,167 and 10,168.—General Electric dissembled clutch as used on clutch type, single phase (KS) induction motor. ***In starting,*** the armature revolves freely on the shaft until approximately 75 per cent. of normal rated speed is reached. The load is then picked up by the automatic action of a centrifugal clutch, which rigidly engages an outer shell, keyed directly to the shaft. The brass friction band of the clutch is permanently keyed to the pulley end of the armature.

External Resistance or Slip Ring Motors.—In large machines, and those which must run at variable speed, such as is required in the operations of cranes, hoists, dredges, etc., it is advisable that the regulating resistances be placed externally to the motor. Motors having this feature are commercially known as ***slip ring motors,*** because *connections are made between the external resistances and the armature inductors by means of slip rings.*



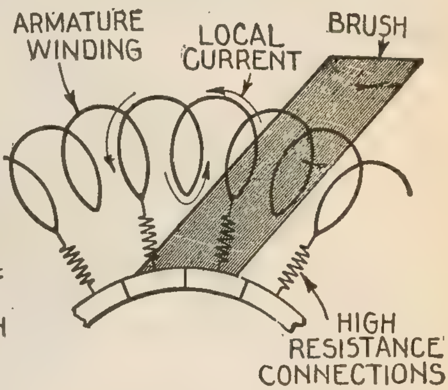


FIG. 10,169.—Diagram of ring armature in alternating current field illustrating commutator motor principles. When a closed coil rotates in an *a.c.* field, there are several different pressures set up as follows: 1. ***The transformer pressure** induced in the armature by the alternating flux from the field magnets.* Evidently the variable flux passing through armature coil is least at the plane AB, because at this point the coils are inclined very acutely to the flux, and greatest at the plane CD, where the coils are perpendicular to the flux. Accordingly, the transformer pressure induced in the armature winding is least at AB, and greatest at CD. The transformer pressure acts in the same direction as the generated pressure as indicated by the long arrows and gives rise to what may be called *local armature currents.* 2. ***The generated pressure** induced in the armature by the cutting of the flux when the armature rotates.* This is minimum at the neutral plane CD, and maximum at AB. It tends to cause current to flow up each half of the armature from D to C, producing poles at these points. 3. ***The self induction pressure** induced in both the field and armature by self-induction.* This pressure being opposite in direction to the impressed pressure it must be evident that in the operation of an alternating current commutator motor, the impressed pressure must overcome not only the generated pressure but also the self-induction pressure. Hence, as compared to an equivalent direct current motor, the applied voltage must be greater than in the direct current machine, to produce an equal current.

FIG. 10,170.—Section of ring armature showing high resistance connectors and ***local armature current.*** These currents produced by the transformer pressure occur in those coils undergoing commutation. They are large, because the maximum transformer action occurs in them, that is, in the coils short circuited by the brushes. Local armature currents cause sparking because of the sudden interruption of the large volume of current, and also because the flux set up by the local currents being in opposition to the field flux, tends to weaken the field just when and where its greatest strength is required for commutation. These local currents may be from 5 to 15 times the strength of the normal armature current and they depend upon the number of turns of the short circuited coils, their resistance and the frequency. Local currents may be reduced: 1, by reducing the number of turns of the short circuited coils, that is, providing a greater number of commutator bars; 2, reducing the frequency; and 3, increasing the resistance of the short circuited coil current either by means of high resistance connectors, or by high resistance brushes.

The armature winding is connected in Y grouping and the free ends connected to the slip rings, leads going from the brushes to the variable resistances as in fig. 10,164.

Failure to Excite.—In starting a dynamo it should be remembered that shunt and compound machines require an

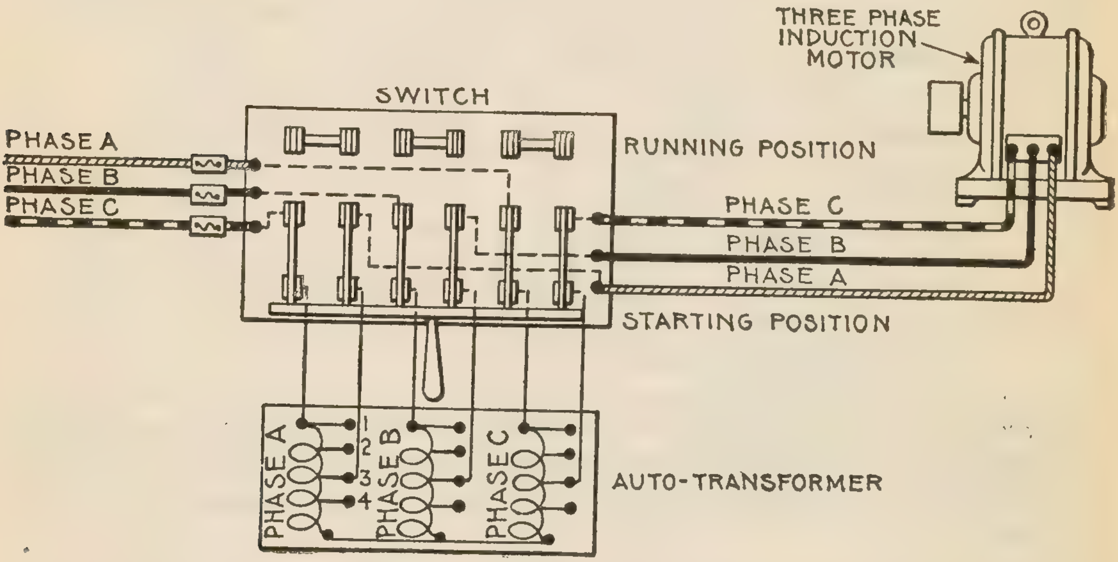


Fig. 10,171.—Auto-transformer of compensator connections for three phase induction motor. ***In operation,*** when the double throw switch is thrown over to starting position, the current for each phase of the motor flows through an auto-transformer, which consists of a choking coil for each phase, arranged so that the current may be made to pass through any portion of it (as 1,2,3) to reduce the voltage to the proper amount for starting. After the motor has come up to speed on the reduced voltage, the switch is thrown over to running position, thus supplying the full line voltage to the motor. ***In actual construction*** fuses are usually connected, so that they will be in circuit in the running position, but not in the starting position, where they might be blown by the large starting current.

appreciable time to build up, hence, it is best not to be too hasty in hunting for faults.

The principal causes which prevent a dynamo building up are:

1. Brushes not properly adjusted;
2. Defective contacts;
3. Incorrect adjustment of regulators;
4. Speed too low;

5. Insufficient residual magnetism;
6. Open circuits;
7. Short circuits;

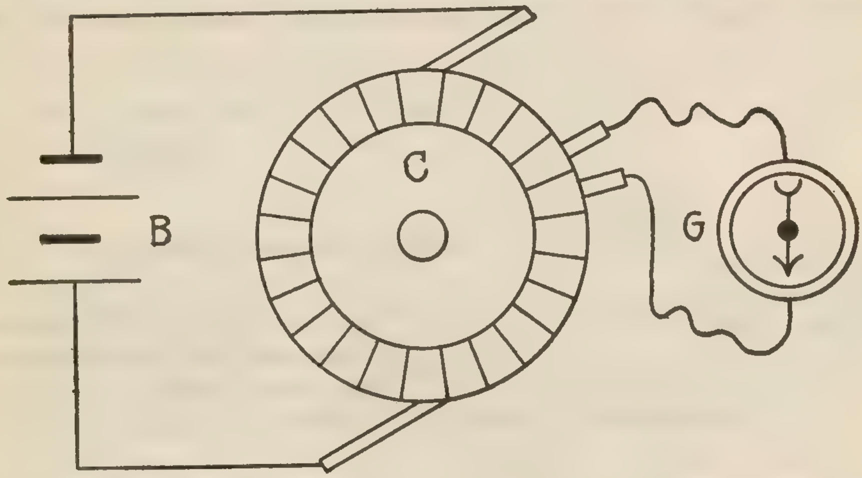


FIG. 10,172.—Method of locating short circuited armature coil. Connect apparatus as shown: pass 20 to 100 amperes from a battery or another dynamo. Now having previously well cleaned commutator, measure voltage between adjacent segments all around. A zero reading will indicate a short circuit, which may be permanent or intermittent; when intermittent it may be carried by wire coming into contact due to centrifugal force developed while armature is rotating.

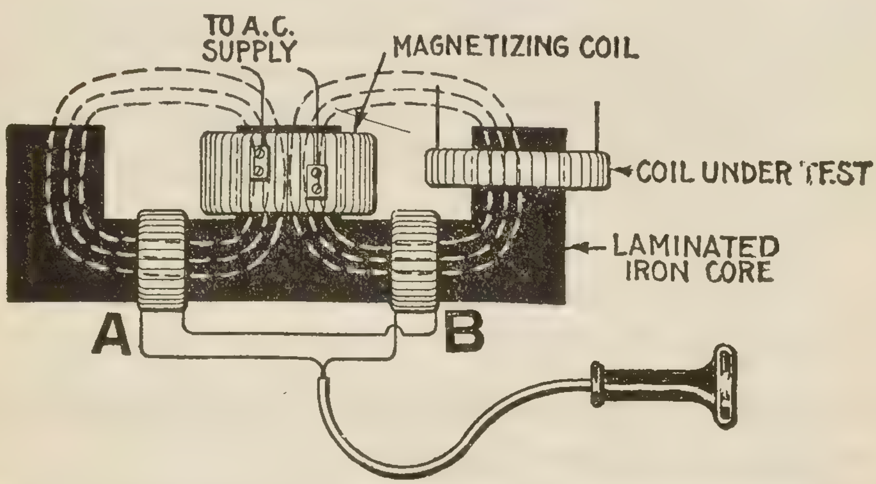
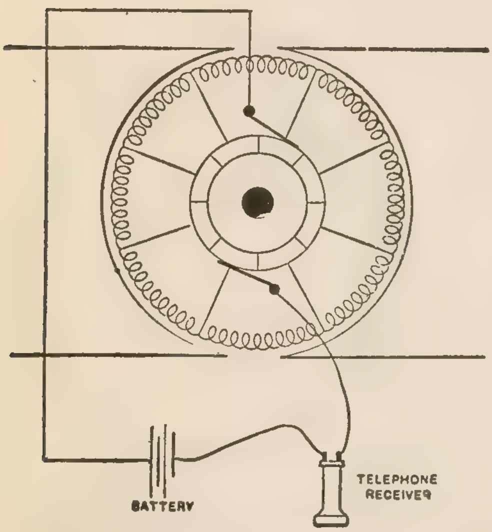


FIG. 10,173.—Field coil testing with telephone receiver. In the method here shown, a telephone receiver is connected in series with two symmetrically placed coils A and B. Very little sound will be heard when the flux through the two coils A, B is the same; but if a short circuited coil is being tested, the fluxes through the coils A, B will not be equal and a noise can be heard in the receiver.

a. In external circuits;
b. In dynamo.

8. Wrong connections;
9. Reversed field magnetism.

Armature Faults.—The chief mishaps to which armatures are subject are:



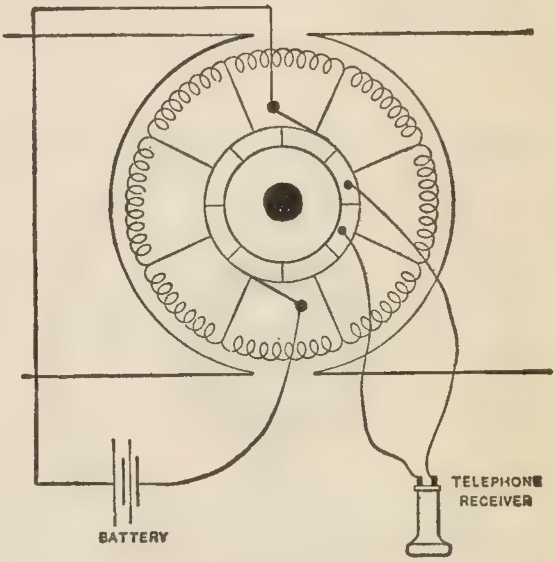


Fig. 10,174.—Test for break in armature lead. Connect apparatus as shown and clean commutator. Rotate armature slowly, telephone receiver "clicks" as brush makes contact with each good segment; a faulty segment gives no response. In making this test brushes must not cover more than a single segment.

Fig. 10,175.—Bar to bar test for open circuit. In coil or short circuit in one coil or between segments. If, in testing as in fig. 10,174 on rotating the armature completely around, the receiver indicate no break in the leads, connect battery as here shown, and touch the connections from the receiver to two adjacent bars, working from bar to bar. The clicking should be substantially the same between any two commutator bars; if the clicking suddenly rise in tone between two bars, it indicates a high resistance in the coil or a break (open circuit.)

1. Short circuits:

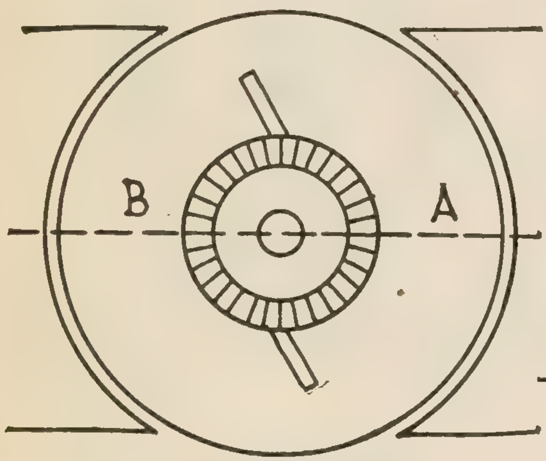
In individual coils between adjacent coils; through frame core; between sections of armature; partial short circuits.

2. Grounds:
3. Breaks in armature circuit.

Commutator Troubles.—In badly designed or constructed

dynamos, sparking occurs at all positions, no matter where the brushes are placed, and in such dynamos it is therefore impossible to prevent this no matter how well they are adjusted.

Sparks due to bad adjustment of brushes are generally of a bluish color; when produced by dirty or neglected state of commutator, the color is reddish and there is a spluttering or hissing sound. The chief causes of sparks are:



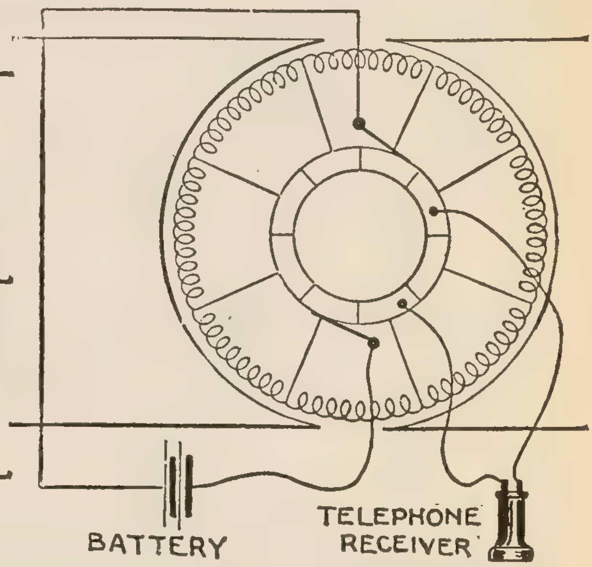


FIG. 10,176.—Method of locating short circuits between adjacent armature coils. Excite fields with coils in parallel. It will now require considerable force to rotate the armature, and then it will move quite slowly, except at one position. When this position has been found, mark the armature at points in the center of the pole pieces at points A and B, and at both ends of the armature. The "cross" or "short" circuit is nearly always found on the commutator end in the last half of the winding, where the wires pass down through the first half terminals. This applies to an unequal winding. In armatures where the windings are equal, it is as liable to occur at one point as at another.

FIG. 10,177.—Alternate bar test for short circuit between sections. Where two adjacent commutator bars are in contact, or a coil between two segments becomes short circuited, the bar to bar test described in fig. 10,175 will detect the fault by the telephone receiver remaining silent. If a short circuit be found, receiver leads should straddle three commutator bars as shown. The normal click will then be twice that between two segments until the faulty coils are reached, when the clicking will be less. When this happens, test each coil for trouble and, if individually they be all right, the trouble is between the two. To test for a ground, place one terminal of the receiver on the shaft or frame of the machine, and the other on the commutator. If there be a click, it indicates a ground. Move the terminal about the commutator until the least clicking is heard and at or near that point will be found the contact. Grounds in field coils can be located in the same manner.

1. Bad adjustment of brushes;
2. Bad condition of brushes;
3. Bad condition of commutator;
4. Overload of dynamo;
5. Loose connections, terminals, etc.;
6. Breaks in armature circuit;
7. Short circuits in armature circuit;
8. Short circuits or breaks in field magnet circuit.

Heating.—When the machine heats, a common mistake is to suppose that any part found to be hot is the seat of the trouble.

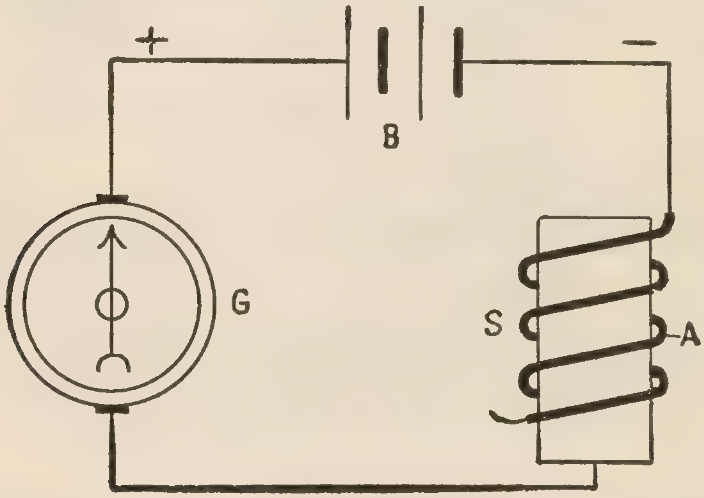


Fig. 10,178.—Method of locating short circuit between coils through armature coil. *Connect* as shown, then connect free terminal of galvanometer to shaft. If then some portion of the wire insulation be abraided or destroyed, as at A, the galvanometer needle will be deflected.

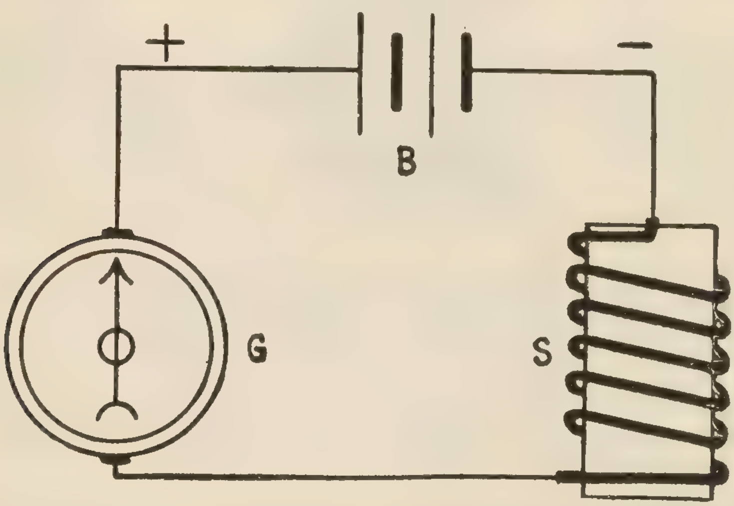


Fig. 10,179.—Method of testing for breaks. Connect as shown. Galvanometer deflection indicates that wire of coil S, being tested is unbroken. No deflection indicates a break or faulty terminal connection.

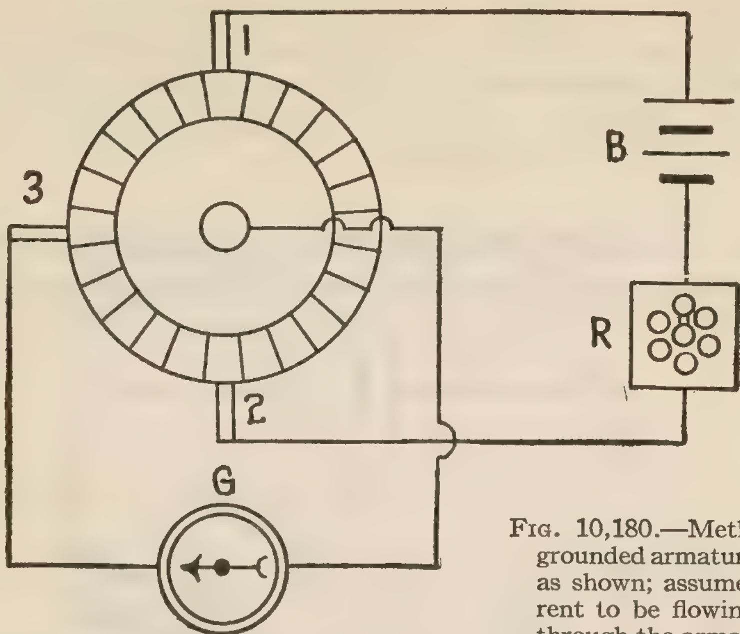
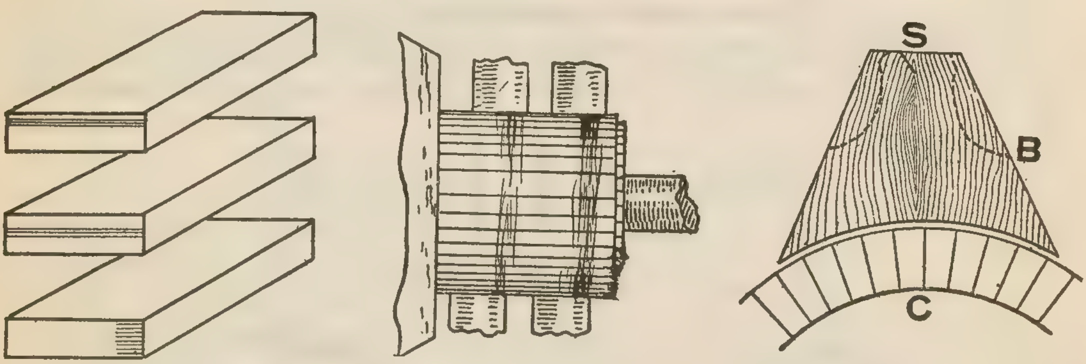


FIG. 10,180.—Method of locating grounded armature coil. Connect as shown; assume a steady current to be flowing from battery through the armature; touch the commutator with brush 3, and a current will flow through the galvanometer. Slowly rotate the armature or the brush 3, until the galvanometer shows no deflection. The coil in contact with 3, will be found to be *grounded*. A rheostat may be inserted in series with the battery or dynamo circuit to regulate the strength of the current passing.

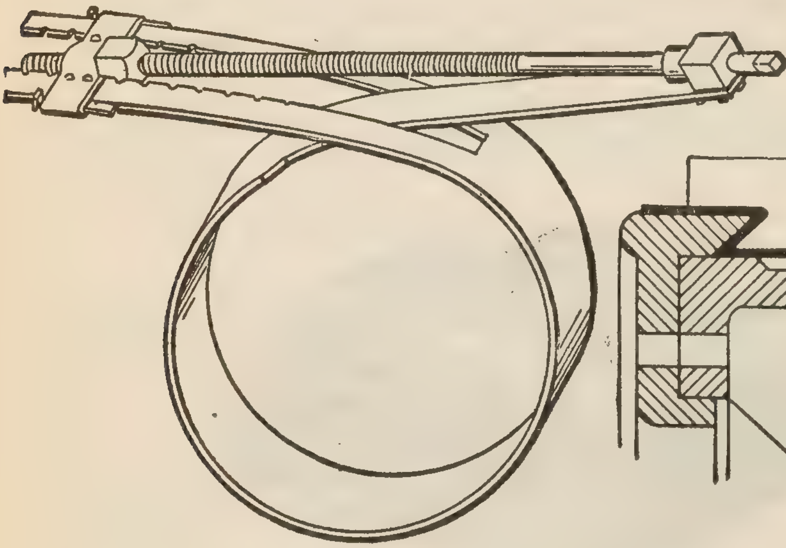


FIGS. 10,181 to 10,185.—Brushes making bad contact. A brush making a bad contact, as only at the shaded portion of figs. 10,181 and 10,182, will not allow the short circuited coil enough time to reverse, causing sparking and heating. The latter will also result from bad contact on account of the surface being too small for the current to be carried off. This form of bad contact is worse than that shown in fig. 10,183, where the area of contact surface only is lessened. If the brushes do not make good contact, they should be ground down.

FIG. 10,184.—Rough and grooved commutator due to improper brush adjustment and failure to keep brushes in proper condition.

FIG. 10,185.—Sandpaper block. ***It is made*** to fit the surface of the commutator. At S, is a saw cut into which the ends are pushed after being wrapped around the block. The latter should be cut down on the dotted lines to form a handle. The dotted line extending to B, indicates the portion of the block cut away to afford a good grip. C, commutator.

Hot bearings may cause the armature or commutator to heat, or vice versa. All parts of the machine should be tested to ascertain which is the hottest, since heat generated in one part is rapidly diffused. This is best done by starting with the machine cold; any serious trouble from heating is usually per-



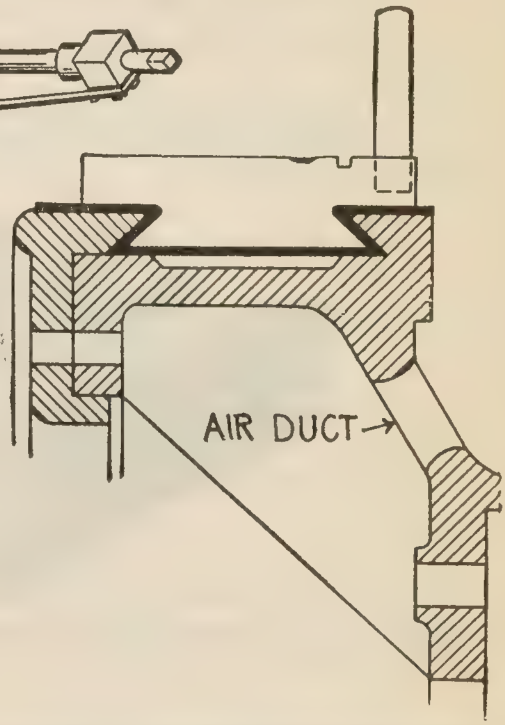


FIG. 10,186.—Commutator clamp; a useful device for holding the segments firmly in position in taking out the end rings of the commutator to repair for internal grounds. ***It is made*** of 2×⅛ inch sheet steel, with a ½ inch screw. The illustration clearly shows the adjustable fastening. The notches fit around rivets on one side of each fastening, which can be moved by removing the two cotters. The clamp is made loose or taut by screwing the bolt in the nut.

FIG. 10,187.—Ventilated commutator; Sectional view showing air ducts for maintaining low temperature.

ceptible after a run of a few minutes at full speed with the field magnets excited.

Heating may be due to various electrical or mechanical causes, and it may occur in the different parts of the machine, as in:

1. The connections;
2. The brushes and commutatot;
4. The field magnet;
5. The bearings.

1. Split Phase Motor Troubles

Speed Too Low.—This may be due to any of the following causes, which may be corrected by the remedies given.

1. Wrong voltage and frequency.

2. Overload. Reduce load on motor or replace with a larger motor if necessary.

3. Grounded starting and running windings. Test out with magneto lamp bell or voltmeter.

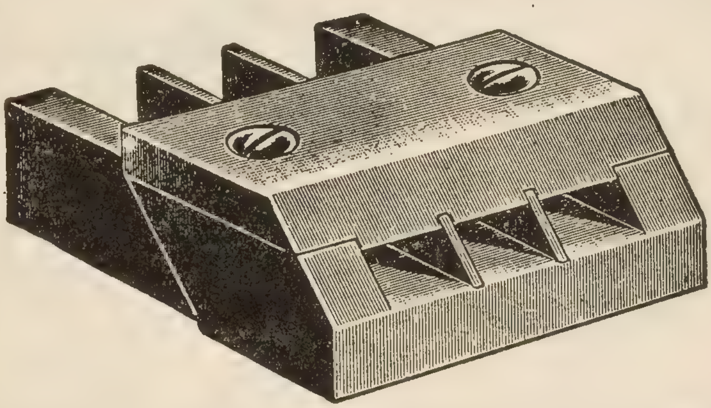


Fig. 10,188.—Jig for filing brushes to the correct level; used with copper brushes to fit them to the commutator.

4. Short circuited or open winding in field current. Test out as above.

5. Too small connection wires. Increase size of wires.

Faulty Starting.—Motor starts, runs slowly, will not pick up to normal full load speed, and blows fuses, due to:

1. Failure of cut out to work properly. Test out cut out for grounds or short circuit. Oil pivots and springs, sand paper rough spots.

2. Grounded plate, test with lamp or magneto, one wire to each slip ring or contact plate.

3. Open circuit in starting or running winding.

Test out with magneto or lamp.

4. Grounded or short circuited starting or running winding.

Test out with magneto, Bell and battery or voltmeter.

Motor Fails to Start.—This fault is sometimes encountered. In such cases

1. Test line voltage with lamp.
2. Test fuses with lamp.
3. Trace out all connections for grounds, open or short circuit.
4. See if brushes be making proper contact with collector rings or contact plates.
5. See that rotor is free to rotate in bearings.

Motor Fails to Start and Hums Loudly.—This may be due to the starting winding being burnt out, open, or grounded.

If motor hum, this indicates that the main or running winding is not open; the motor may be started by rotating the armature by hand until it reaches its normal rated speed.

Sparking at the Brushes.—As the brushes of split phase motors are only used in starting, sparking may be due only to worn and loose brushes, or dirty slip rings.

Clean slip rings with a benzine soaked rag. Apply a little vaseline with the finger to each slip ring to prevent cutting by the brushes.

Heating of the Windings.—This may be due to any of the following causes:

1. Moisture in windings. Dry out in an oven.
2. Short circuit or ground. Test out with magneto, lamp, bell or voltmeter.
3. Overload. Reduce load or install a larger motor.
4. Too low line voltage. Check up with voltmeter.
5. Too high line voltage. Any voltage in excess of 5% on 220 volts, 10% on 110 volts should be reduced at this will cause the windings to burn out.

6. Wrong frequency. A 40-cycle motor cannot be used on 60 cycle current as the rotor will not revolve in synchronism with the alternator.

7. Wrong voltage connections to motor.

8. Connection wires too small. This will cause a voltage drop.

Heating of the Rotor.—This is usually caused by overloading

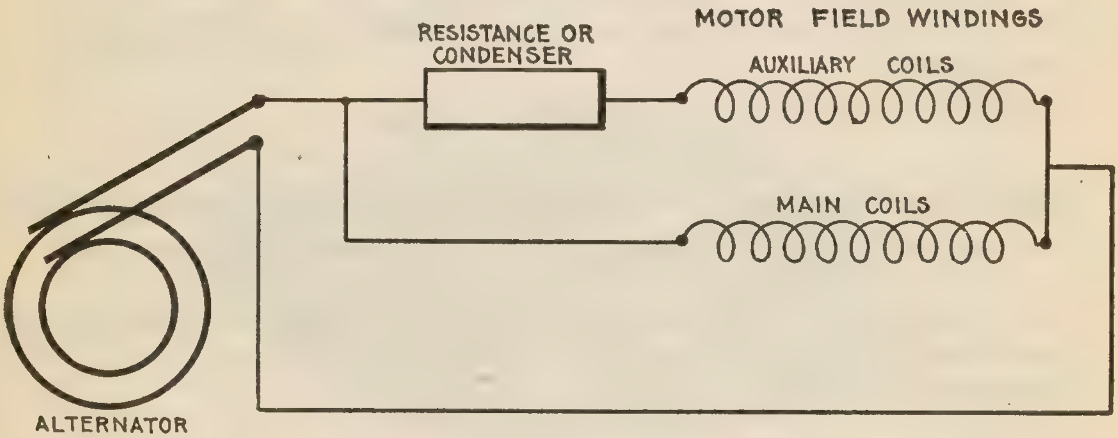


FIG. 10,189.—Simplified diagram showing the principle of phase splitting for starting single phase induction motors. ***By the use*** of an auxiliary set of coils connected in parallel with the main coils and having in series a resistance or condenser as shown, the single phase current delivered by the alternative is "split" into two phases, which are employed to produce a rotating field on which the motor is started.

the motor or by broken soldered connections of end bars. Reduce load or solder broken connections.

2. *Fractional Horse Power Motor Troubles*

Motor Fails to Start.—Be sure that the wires connected to the motor terminals make good contact; that each of the brushes of the motor makes perfect contact with the commutator; that the connected load is not too great for the size of motor used.

Motor Hums Loudly and Refuses to Start.—The fault may be due to

1. Short circuited field windings.
2. Grounded connections, or cut out switch.

Test out individual windings with volt meter, holding one wire to frame, the other to each lead of field windings.

Test out cut out switch with magneto, one wire to shaft the other to each half of cut out plates.

Motor Runs Too Slow.—This fault may be due to

1. Burnt out, short circuited, or grounded winding.
2. Grounded cut out switch.
3. Cut out switch refuses to short circuit itself.

This may be due to corroded springs, dirty plates, dirt in springs and pivots.

Care of Compensators.—These should be inspected once a year and the oil changed. Use only oil as furnished with the compensator by the manufacturer, as this has been found to give the best results; any other grades of oil will cause a lot of unnecessary trouble.

If the contact fingers on the switch of the compensator be scorched or burnt they should be smoothed with a piece of sand paper, if they be too far burnt or worn, they should be replaced with new ones.

Tighten all springs on switch and no voltage release, so that contact fingers press firmly on all contact.

Oil all exterior moving parts of switch handle, also the no voltage release.

Grounding of Compensators.—The cases of all compensators should be grounded especially when installed on high voltage circuits, to insure safety to the operator if for any reason the current carrying parts should accidentally come in contact with the case.

A good contact is obtained by securing the ground wire under a screw or bolt on the compensator.

The ground wire should be run to a water pipe as required in the *Code*.

3. Compensator Troubles

Motor Fails to Start.—If the fuses and motor be in good condition, examine all contacts and see if contact fingers make contact.

Press with a screw driver all contacts and see if motor start. Trace out all leads from terminal block to contacts. Examine all transformer taps. In case of a burn out on one coil of a three phase compensator the coil may be cut out by a slight change in connections and the compensator used temporarily until a new set of coils can be obtained.

Compensator Hums.—This is due to an improper sealing surface of the no voltage release or loose laminations of the solenoid or transformer.

Tighten all screws on the no voltage release solenoid plunger and no voltage coil, also tighten screws on transformer.

No Voltage Release Fails.—If the no voltage release fail to hold switch in running position, the fault may be due to:

1. Burnt out no voltage coil.

   Test with a magneto.

2. Wrong connections.
3. Latch of no voltage release stuck.

   This may be due to dirt or foreign object. Remove same.

4. Overload relay plunger stuck.

   This causes an open circuit in the no voltage release circuit. Inspect all relays, and try moving by hand, and note if they make contact.

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